

The AMSAT[®] Journal

Editor

Russ Tillman, K5NRK

Editorial Staff

Ron Long, W8GUS

Andy Reynolds, WD9IYT

John Bubbers, W1GYD

Volume 23, No. AO-40 — Special Phase 3D Launch Issue — November 2000

CONTENTS

Phase 3D Soars into Orbit as
AO-40..... 1 & 4

Apogee View.....3
By Robin Haighton, VE3FRH

RUDAK Telemetry Summary:
V1.0 - 16NOV000.....6
By Jim White, WD0E

An Overview of the Electronic
Modules on the AMSAT Phase 3D
Satellite.....9
By Peter Guelzow, DB2OS

Tuning Up! - Making Your Phase
3D Station Active.....17
By Franz J. Bellen, DJ1YQ

Phase 3D Telemetry Program
Available.....21
By Stacey Mills, W4SM

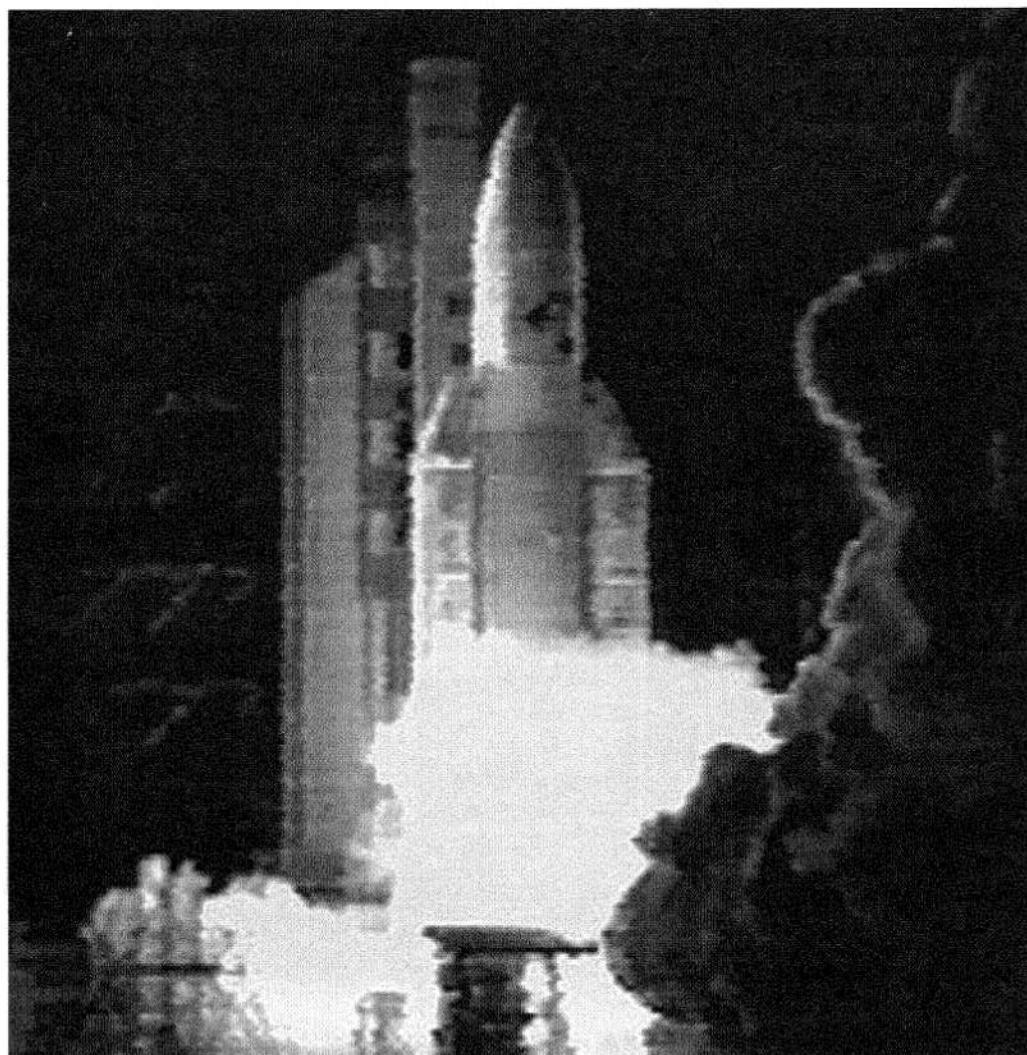
Field Ops Update: Publicizing
AO-40.....22
By Barry A. Baines, WD4ASW

Viktor Kudielka, OE1VKW Answers
AO-40 Propulsion Questions.....25

Perspectives on AO-40's Orbital
Evolution: A 2001 Space
Odyssey.....26
By Ken Erlandes, N2WWD

Phase 3D Frequencies.....28

The Phase 3D Launch Campaign:
A Photo Essay from Kourou.....29
By Dick Daniels, W4PUJ



Liftoff! The successful launch of the Phase 3D satellite from Kourou, French Guiana. Launched by Arianespace on the Ariane 5 V-135 flight, Phase 3D began its long and exciting journey at 0107UTC on 16 November 2000. Radio Amateurs from around the world closely monitored the launch via HF, satellite, and Internet links. See accompanying launch article on page 4. (Photo: Arianespace)

AMSAT-NA
850 Sligo Avenue, Suite 600
Silver Spring, MD 20910-4730 USA

Periodicals

POSTAGE PAID

At Silver Spring, MD
and at additional
mailing offices

One good launch deserves another.

More Power.

100W UHF/75W

UHF. Phase 3D Ready.

Easy to Use Soft Key Menus.

Dual 9600 bps PACKET Ports. Go

Anywhere Size. 1.2 GHz & DSP Capable.



The IC-910H. A new era in satellite transceivers.

100W VHF/75W UHF Variable Output • Simultaneously Works Two Bands at Once • Dual 9600 bps High Speed PACKET Ports • All Mode • .11 uV Sensitivity • Main & Sub Band Functions for IF Shift, Sweep, NB, RF Attenuator • Large LCD Display • Four Versatile Scanning Functions • CTCSS Encode/Decode/Tone Scan • Built-in Keyer • PC Controllable • Memory Pad • Reverse Satellite Functions • Optional 1200 MHz Band Unit • Optional DSP



ICOM congratulates AMSAT on the successful launch of the Phase 3-D satellite.

*This device has not been approved by the FCC. This device may not be sold or leased, or offered for sale or lease, until approval of the FCC has been obtained.
©2000 ICOM America, Inc. 2380 116th Ave NE, Bellevue, WA 98004 • 425-454-8155. The ICOM logo is a registered trademark of ICOM, Inc.
All specifications are subject to change without notice or obligation. 910H-P3D1100

Begin your new era here.

www.icomamerica.com

ICOM®



Radio Amateur Satellite Corporation (AMSAT-NA)
850 Sligo Ave., Silver Spring, MD 20910-4703
Telephone: 301-589-6062 Facsimile: 301-608-3410
AMSAT-NA Club Callsign - W3ZM
AMSAT-NA WWW: <http://www.amsat.org>

The AMSAT Journal Staff

Vice President, Publications: Russ Tillman, K5NRK
Circulation: Martha Saragovitz
(martha@amsat.org)
Ron Long, W8GUS
Andy Reynolds, WD9IYT
John Bubbers, W1GYD

AMSAT-NA Board of Directors

Bill Tynan, W3XO (Chairman); Keith Baker, KB1SF;
Tom Clark, W3IWI; Dick Daniels, W4PUJ;
Robin Haighton, VE3FRH; Andy MacAllister, W5ACM;
Barry Baines, WD4ASW

AMSAT-NA Officers

President:
Robin Haighton, VE3FRH
Executive Vice President:
Ray Soifer, W2RS
Vice President, Operations:
Keith Pugh, W5IU
Vice President, Engineering:
Stan Wood, WA4NFY
Manager, Orlando Laboratory:
Lou McFadin, W5DID
Vice President, Human Space Flight:
Frank Bauer, KA3HDO
Vice President, Field Operations:
Barry Baines, WD4ASW
Vice President, User Services:
Andy MacAllister, W5ACM
Vice President, Electronic Publication:
Paul Williamson, KB5MU
Vice President, Development:
Harwood Sheppard, AA7MH
Vice President, Strategic Planning:
Bill Burden, WB1BRE
Vice President, Public Affairs:
Dan James, NN0DJ
Vice President, Education Liaison:
Steve Bible, N7HPR
Founding President Emeritus & VP, Government Liaison:
Perry Klein, W3PK
Treasurer:
Art Feller, W4ART
Corporate Secretary:
Martha Saragovitz
President Emeritus:
Tom Clark, W3IWI
Immediate Past President:
Keith Baker, KB1SF

Editorial Office: Russ Tillman, K5NRK, 110 Camden Drive,
Vicksburg, MS, 39183-1203, Internet: k5nrk@amsat.org,
telephone: 601-634-6398, and fax: 601-638-2131.

Advertising Office: AMSAT-NA Headquarters, 850 Sligo Avenue,
Suite 600, Silver Spring, MD 20910-4703.

The AMSAT Journal (ISSN: 1407-3076) is published bi-monthly
(Jan, Mar, May, Jul, Sep, Nov) by AMSAT-NA, 850 Sligo Avenue,
Suite 600, Silver Spring, MD 20910-4703. Telephone:
301-589-6062, fax: 301-608-3410. Periodicals postage paid at
Silver Spring, MD, and additional mailing offices. Postmaster, send
address changes to The AMSAT Journal, 850 Sligo Avenue, Suite
600, Silver Spring, MD 20910-4703.

Opinions expressed by The AMSAT Journal are those of the article
author and not necessary those of AMSAT-NA. Copyright ©
2000 by AMSAT-NA, The Radio Amateur Satellite Corporation.
AMSAT is a registered trademark. Reproduction material from The
AMSAT Journal, mechanical, electronic, or photocopy, is prohibited
unless written permission is obtained from the author.

The AMSAT Journal staff is always interested in article submissions.
Whenever possible, text should be on IBM compatible diskettes
with hardcopy or original photographs or figures. AMSAT-NA
reserves the right to select material for The AMSAT Journal based
on suitability of content and space considerations. The editors of
this publications are volunteers giving freely of their talents, time,
and efforts to produce The AMSAT Journal.

A New Era in Amateur Satellite Communications

After all the years of waiting and the various promises of delivery, Phase 3D is finally in space as AO-40. A big thank you to all who have worked so hard in the development of this project.

AO-40 is truly an international satellite with contributions of hardware and software from all over the world, and many thanks to those who have spent many hours during the design, build and integration stages as well as those who donated their holidays to be at Kourou for the final testing and preparation prior to launch.

However there is one group of people who are also the unsung heroes of this operation, **YOU** the readers of this Apogee View, who have donated much of the finance which enabled Phase 3D to be built, tested, transported to the launch site and launched. Without your aid, planning conferences could not have been held, teleconferences would not have happened, and many component parts could not have been purchased. **In appreciation for your continued support, this special issue of The AMSAT Journal is dedicated to you and your fellow AMSAT members worldwide who went the extra mile to get Phase 3D built and in orbit.**

It would be a major task to mention all of those who have assisted in the Phase 3D project. However I should mention that the major load of design, and development has fallen on AMSAT-DL and also that the launch crew was headed up by their Vice President Peter Guelzow, DB2OS to whom we must offer a vote of thanks.

The next thing you must do is ENJOY the fruits of this work, AO-40 should last for many years, until eventually the ravages of space will start the aging process. We hope that within a few months AO-40 will be in it's final orbit, and that the various bands will be open for your use. At the time of this writing we do not know if all of our systems are fully operational but the expectations are high and time will tell. Unfortunately, with a satellite as complex as AO-40 and the number of operating modes it will be virtually impossible to please everybody 100 percent of the time, but I hope that we will be able to reach a reasonable

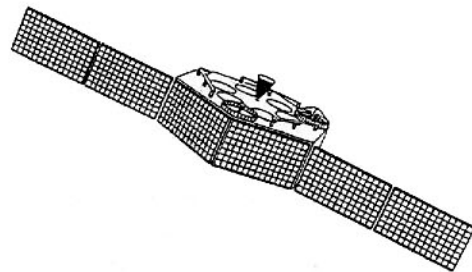
compromise to allow ragchewers, contesters, and experimenters sufficient operating time on the different bands to meet their needs.

To keep a satellite such as AO-40 operational, requires some funding, in addition we estimate that AMSAT-NA has overspent the Phase 3D income by approximately eight percent, while remaining on the overall budget as proposed at the beginning of the project. Thus in order to proceed with other projects we need to raise a further \$320,000. Not a large sum when spread amongst all the members of AMSAT-NA, and I am confident that each and every one of you will want to contribute to help eliminate any debt in the Phase 3D account.

Already many of our members are speculating on the next major AMSAT project, and I can advise you that AMSAT is continuing to support Amateur Radio on the International Space Station (ARISS) with equipment and personnel, which includes the amateur equipment sent to ISS in September of this year and is already in use. New equipment will be sent to ISS Alpha as the project expands and this requires considerable support from AMSAT. In addition AMSAT is reviewing several proposals sent to the AMSAT project committee, some of which were also the subjects of papers given at the recent AMSAT annual meeting in Portland, Maine.

So please assist us to meet our goal to overcome our Phase 3D debit, thus allowing the next major project to be selected, designed, and built. Send your donation to Martha at AMSAT-NA, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703, USA, made out to **AMSAT Phase 3D Fund**.

73 de Robin Haighton, VE3FRH ■



**Phase 3D Successfully Launched into Orbit as
AO-40! 0107 UTC, 16 November 2000**

Phase 3D Soars into Orbit as AO-40!

A new era in Amateur Radio communications was ushered in at 0107 UTC on 16 November 2000 as AMSAT-DL Executive Vice President and Phase 3D Mission Director Peter Guelzow, DB2OS, informed AMSAT members from around the world that the launch of the Phase 3D satellite from the European Spaceport in Kourou, French Guiana was successful. It was a spectacular night time launch.

"It was a textbook launch" said DB2OS, "from the first minute of flight, until Phase 3D separated from the Ariane 5 launch vehicle, all received telemetry indicates the launch went perfectly and our satellite appears to be in very good health."

Launched via the Ariane 5 V-135 mission with three other satellites - the large PAS-1R communications satellite and the smaller STVR-1C and 1D satellites, Phase 3D was placed into geo-stationary transfer orbit, from where it will be nudged into its final elliptical orbit.

The Ariane 5 flight proved to be a record setting mission as it marked the first use of the ASAP-5 platform. The ASAP-5 enables the launcher to carry auxiliary micro and mini satellite payloads. By coincidence, Phase 3D was married to the PanAm-1R satellite, which was also the case when the first Ariane 4 (flight 401) rocket also launched both an AMSAT and a PanAm satellite.

On this launch, PAS-1R becomes the largest commercial satellite ever put into orbit —

and Phase 3D the largest Amateur Radio satellite ever built and launched.

At liftoff the Ariane 5 launch vehicle mass was over 6,200 kg (almost 13,700 lbs.)! This included the mass of the PanAmSat primary payload and the three auxiliary satellites (of which Phase 3D was one), as well as the mass of the ASAP-5 platform and the other payload mounting and interface hardware.

AMSAT-NA President Robin Haighton, VE3FRH, welcomed the news of the launch, noting "that the design, building and financing of Phase 3D by international volunteers is a great achievement."

Immediate AMSAT-NA past President Keith Baker, KB1SF, told ANS that he was "delighted" by the news of the Phase 3D launch. "Obviously this is a big thrill for all of us who have spent the better part of our lives over the past ten years bringing the satellite to fruition. I have no doubt that today will be regarded as one of the greatest days in the history of Amateur Radio."

ANS also received word from AMSAT-NA Board of Directors Chairman (and past AMSAT-NA President) Bill Tynan, W3XO. "I can't begin to tell you how happy I am to see Phase 3D in orbit," said Tynan. "As I followed the launch sequence, I thought of the many people who have been involved with this project from the very beginning and how pleased everyone must be to see the reward of such hard work."

Although safely in orbit, there is much work to be done with Phase 3D, now called AO-40 (see box) before the satellite is opened for

general Amateur Radio use. Initial housekeeping tasks are now underway to verify the health of the many complex systems onboard - followed by bringing these systems online. As previously noted Phase 3D is now in a transfer orbit used for geosynchronous satellites.

To move Phase 3D from this orbit the arcjet motor will burn intermittently (at perigee) over a 270-day period, with final inclination and apogee adjustments made by the spacecraft's 400 Newton motor. "When these maneuvers are completed and three-axis stabilization is achieved, the satellite solar panels will then be spread out to receive full sunlight," said Haighton. "It is anticipated that at this time the satellite will be fully operational for use by Amateur Radio operators around the world."

Immediate Launch Reports

Throughout the world, Radio Amateurs assembled to monitor the launch via HF and Internet nets. In addition, the launch was televised to Europe and North America via satellite transponders. Within hours after launch, numerous reports were posted on amsat-bb by Radio Amateurs from around that world confirming that AO-40 telemetry had been received on 145.898 MHz (See Tables 1a and 1b).

Phase 3D Re-named AO-40 After Launch

AMSAT-NA Chairman of the Board Bill Tynan, W3XO posted the following message to amsat-bb shortly after launch:

K HI, This is Amsat Phase 3D, the international spacecraft to support science/education, amateur space communication and above all international friendship.

* THANKS KARL *

L HI, Hier ist Amsat Phase 3D, der intern, Satellit zur Foerderung von Wissenschaft, Amateurfunk und vor allem internationaler Freundschaft und Zusammenarbeit.

* DANKE KARL *

M QST AMSAT PHASE 3-D DP0WH

IN MEMORIAM WERNER HAAS, DJ5KQ, Vice President AMSAT-DL + 13.06.2000 +

N HI, Ici Amsat Phase 3D satellite international pour support a la recherche scientifique, aux amateurs de communication spatiales ainsi qu'au tous les amis d'une cooperation internationale.

* MERCI KARL *

P3D IHU-1 Telemetry Display - OE1KIB, OE1VKW

A HI, THIS IS AMSAT P3-D 2000-11-16 12:21:03 #0010

P3D is alive and well!! 73 from the AMSAT P3D Team |

Orbit Data

- AMSAT day 08355 Time 12:21:03.82 UTC Orbit No 00000 Phase 237

Table 1a. Within hours of launch, Victor Kudiekla, OE1VKW provided amsat-bb with one of the first telemetry reports from AO-40.

Hi All:

Following its successful launch at 0107Z on 16 November 2000 the spacecraft so many have been working on for the past 10 years, now has a new name. We have been calling it Phase 3D for far too long.

Henceforth it will take in place in the long line of OSCARs, satellites built by the Amateur Radio community for the Amateur Radio community throughout the world.

Dr. Karl Meinzer, DJ4ZC Project Leader for Phase 3D, has officially requested it be given an OSCAR number, and under the authority vested in me by our new AMSAT-NA President Robin Haighton, VE3FRH to be the "Keeper of the OSCAR Numbers," I hereby christen our newest, and proudest bird, AMSAT-OSCAR 40. It is certain to be known as AO-40.

AMSAT-OSCAR 40 is dedicated to the memory of one of its principal builders Werner Haas, DJ5KQ and operates under the call sign DP0WH, the "WH", of course being Werner's initials.

Congratulations and thanks to all who participated in any way to this wonderful achievement.

AO-40 Telemetry Decoding Software Available via AMSAT France

AMSAT-France Secretary Jean-Louis Rault, F6AGR reports that some DOS programs have been developed to decode and display AO-40 telemetry transmissions (available via <http://www.amsat-france.org>). The first program, called pskdem.exe was developed by Ghislain, FIHDD, converts 400 bds PSK sound files into p3d.tlm files containing the binary data stream. A second program, called tlmdec.exe uses OE1KIB/OE1VKW data to convert the binary data into a fully decoded information (voltages, temperatures, status, etc). Some instructions on using this software are:

- Download the full package from AMSAT-F site
- Record BPSK 400 baud signals (using Window Tape Recorder for example). Use a USB receiver giving an audio center frequency located somewhere between 1200 and 1600 Hz
- Measure carefully the audio center frequency (using Spectrogram or CoolEdit)
- Run pskdem.exe and type the measured center audio frequency
- Run tlmdec.exe to get the decoded data on the PC screen.

This software package is a freeware. Processing is limited to about 360,000 characters. AMSAT-F is also developing a Windows version which should soon be available. This program, uses a FFT display and will allow an easy tuning of the center frequency. The program is intended to convert audio PSK streams into binary files. Any remarks to be sent to Ghislain, FIHDD (ruygh@attglobal.net) or to F6AGR (f6agr@amsat.org).

Status

- RX: U(-1.3dB) L1(0.7dB)
- TX: V(0x7eW MB)
- Beacons: GB(PSK;) MB(EB source; V)
- Antennas: #129=0xae
- Ant/Pre-amps: U-Rx=om U-Tx=hi L-om+preamp
- Experiments: IHU-2 Cedex-ctrl Cedex-pwr
- Main battery on; Charger on; Memory soft error count: 4
- Temperatures [C]
- SolPan1 -5.8 SolPan2 4.8 SolPan3 5.4 SolPan4 4.8 SolPan5 4.8
- BCR1 10.7 BCR2 19.3 BCR3 16.0 SolPan6 -5.1
- MainBatB2 20.6 MainBatB4 20.6 MainBatB6 -5.8 AuxBatB1 16.6 AuxBatB5 19.3
- V-TX 36.4 U-Excit 15.3 U-Amp 17.9 S1-TX 21.2 S2-TX 21.2
- X-TX 86.5 X-TX TWT 88.9 K-TX -51.2
- U&V-RX 21.2 L1-RX 19.9 L2-RX 12.7 S1-HF RX 14.7 S2-C RX 14.0
- IHU 5.4 SEU 4.1 EPU 19.9 RF monit -51.2 S ant 18.6
- HP1+X-Y 17.3 HP2+X+Y 22.6 HP2+X-Y 22.6 HP2-X 23.2
- HP3+X 19.9 HP3-X 20.6 HP4+X+Y 21.9
- NH3 B2 22.6 MMH B3 22.6 N2O4-X-Y 22.6 N2O4+X+Y 21.2 He Tank 27.2
- Top 50.9 Bottom 17.9 Back 14.0 Side2Pan 11.4 Side4Pan 10.7

Voltages [V]

- Main-Bat 27.6 Aux-Bat 27.2 BCR1-In 25.7 BCR2-In 21.5 BCR3-In 17.0
- 28V Bus 27.3 10V-C1 BCR2 12.5 10V-C2 BCR3 12.6

Currents [mA]

- SP1-BCR1 2421 SP4-BCR2 7998 SP2-BCR3 89
- SP6-BCR1 6781 SP5-BCR2 89 SP3-BCR3 89
- 10V-C1 BCR2 213 10V-C2 BCR3 350 28V-S SEU 0x07
- 28V-Bat -914 28VU1EPU -1 28VU2Bus 6353 28VU3-S -18 28V-BCR 5081
- 28VS-PA/M -33 10VS-PA/M 0x07 X-Helix 3 K-Tx 0x07

Sun/Earth Sensors

Sensor mode: spin

- SS1 PLL: locked SS2 count: 41SpinRate[rpm] 2.7
- SS Z -25 -27 SS Y -25 -27 SS Up -X 3 SS Up -Y 3
- SS Z -45 -47 SS Y -45 -47 SS Dwn -X 3 SS Dwn -Y 3

Momentum Wheels

Arcjet Motor

- Tank Pressure 4Bar Motor Pressure 5Bar
- Motor Current 0.2A Motor Voltage -237.4V Flow 0x07

400 N Motor

- Motor valve: closed High pressure: -169Bar Low pressure: -0Bar

P3D IHU-1 Telemetry Display — End of Block

Table 1b. Continuation of AO-41 Telemetry collected via OE1VKW.

RUDAK Telemetry Summary: V1.0 - 16NOV00

Jim White, WD0E

This article provides some detail about the RUDCOEFX file and how telemetry (TLM) is sent by the RUDAK experiment on AO-40. The RUDCOEFX file contains the telemetry point definitions for AO-40 RUDAK originated telemetry and the coefficients used to calculate the engineering values from the raw counts sent on the downlink.

Discussion

The RUDCOEFX file contains the coefficients for all telemetry channels that originate in the RUDAK A and B processors as well as the two CAN temperature nodes. It is organized into sections headed by a line indicating which processor the data following applies to. Data for the RUDAK A processor is first, followed by the data for the CAN temperature nodes as read by RUDAK A. The next section is data sent by the RUDAK B processor. This is followed by the same CAN temperature information (included for software convenience). The last section is notes about the organization of the file.

In the sections for the RUDAK data the columns are as follows, starting on the left:

- Channel number in hex
- Channel name
- c, b and a coefficients in the formula $ax^2 + bx + c$, where x is the counts sent on the downlink
- Units

In the CAN temperature sections the columns are:

- Channel number in hex
- Channel name
- a, b, c, d, e, f in $ax^5 + bx^4 + cx^3 + dx^2 + ex + f$, and x is counts
- Units

There are two processors in the RUDAK experiment, called A and B. Each can read some voltage and current TLM from the other. Only the A processor reads the TLM from the DSP board. That data is only valid when the DSP board power is turned on. In order to conserve power the DSP board will only be on when in use.

Telemetry Value Discussion

Looking first at the RUDAKA points:

- '5V Reg Temp' point reads the temperature of the 5V regulator that supplies power to the A processor. The RUDAK experiment is fed from the 10V rails in the satellite and produces its own 5V supply.
- 'Mem Temp' point provides the temperature of the EDAC memory on the RUDAK A processor board.
- '10V Sw V' is the voltage on the 10V rail feeding RUDAK A.
- '10V Sw V B' is the voltage on the 10V rail feeding RUDAK B.
- '5V V B' is the 5V regulator output on the B processor.
- 'VCC I B' is the current being drawn by the B processor on the 5 V line.
- 'VCC I' is the current drawn by the A processor on the 5 V line.
- '5V V' is the voltage provided by the 5V regulator on the A board.
- 'DSP I' A side and B side point measures the current drawn by the DSP board. These data are only valid when the DSP board power is on but they are in the TLM stream all the time. The DSP board contains hardware for both processors. Components are arranged with those serving the A processor on one side and those serving B on the other.

The DSP temperatures are labeled according to the component they are next to or attached to.

The 'Top sideA Tmp' reads a thermistor attached to the top cover of the RUDAK box above the A DSP board side.

'Vreg A Temp' is the temperature of the regulator that supplies power to the A side of the DSP board.

Other points are similarly labeled.

The accelerometer attached to the outside of the RUDAK module box is reported on channels 1A through 1C as the raw counts from the device. Calibration remains TBD on orbit.

Channels 1D through 2E report software values and flags.

- 'WODF state' reports the state of the Whole Orbit Data function. 0 is not running, 1 is starting to collect WOD, 2 is collecting and 3 is stopping.
- 'Digi Status' reports the state of the digipeater. 1 is on, 0 is off. This is also reported in the LSTAT line as the d: parameter.
- 'PHT Time' is the rate in seconds at which the housekeeping task (PHT) is cycling through the routine functions. Normally this is the rate at which the TLM, LSTAT and TIME packets will appear in the downlink, although that can be adjusted so TLM can be gathered and stored faster than it is sent on the downlink.
- 'DSP RX select' indicates the uplink receiver that is switched to the DSP input.

- '153k6 RX sel' indicates the uplink receiver switched to the 153k6 demod. This value and 'DSP RX select' will only be valid after a command has been sent to set them.
- 'IHU pass stat' indicates the status of the function that repeats IHU frames on the RUDAK downlink. 1 = on, 0 = off. At times IHU frames will be repeated by RUDAK. The telemetry frames (A blocks) are broken into three packets, the text portion, the analog portion, and the digital points. Other frames are also broken into three packets with about the same number of lines in each packet.
- 'TLM Ratio' indicates the ratio of the number of TLM packets gathered for every frame sent on the downlink. For example if this value is 5 every fifth TLM data set will be sent on the downlink. Initially this will be 1, but later it may be set higher to allow TLM to be gathered and stored as WOD at a faster rate than it is sent on the downlink. For example if PHT time is 10, TLM Ratio is 6, and WODF state is 2, TLM is being gathered and stored to the file system every 10 seconds but only sent on the downlink every 60 seconds. This might be done to reduce the loading on the downlink.
- "Msg 2 Ratio" is unused at this time.
- 'Text Msg Ratio' indicates how often the general text broadcast message is sent on the downlink. This is a multiple of PHT Time. For example if PHT Time is 10 and the Text Msg Ratio is 6 the text broadcast will be sent every 60 seconds.
- '9k6 0 out lvl' is a value that indicates the setting of the output level adjustment on the first hardware modulator, mod 0. This level can be set to balance the amount of transmitter power RUDAK uses with that available for other signals.
- '9k6 1 out lvl' is the output level of the second hardware 9k6 modulator.
- '153k6 out lvl' is the output level of the 153k6 PSK modulator.
- 'IHU A cnt' is the count of the number of IHU telemetry frames repeated by RUDAK. This count is reset only when it wraps or when a new PHTX software task is loaded.
- 'IHU othcnt' is the count of the number of other types of frames repeated by RUDAK. This count resets only on wrap or when a new PHTX software task is loaded.
- 'CANsvrstat' indicates the state of the CAN session in the housekeeping (PHTX) task. 1 = session established, 0 = no session.
- 'CANst40/50' indicates the status of the last attempt to read data from the CAN temperature nodes. 0 = no error.

In the Can temperature section the name of the value indicates where the thermistor is placed. The references are to locations on the heat pipes in various modules or the heat sinks of transmitters or experiments. Refer to the diagram of the AO-40 equipment bays for further detail.

Frames

Telemetry frames are sent to the callsign 'TLMI.' The A processor callsign is 'RUDAKA', the B processor is 'RUDAKB.' The telemetry frames from

each processor can be two lengths. If a CAN session is not active only the local RUDAK values are sent. CAN temperatures will be included in the packet if a CAN session is active. RUDAK A sends the data points from the DSP board in every frame but they are valid only if power is on to that board.

TLM Data Format

TLMI packets are AX.25 UI frames. The data portion consists of a 4-byte time stamp followed by the data points.

The time stamp is in DOS time format; the number of seconds since January 1, 1970. RUDAK time is always UTC.

Each data point is three bytes. The first byte is the channel number as a hex value matching that in RUDCOEFX. The next two bytes contain the counts as read by the A to D converter. They are sent high order byte first (C int format).

There will be as many data points as there are channels in the appropriate section of RUDCOEFX (See Figures 1a and 1b).

Notes

Sections RUDAKA and RUDAKB are for the A and B processors respectively.

Section RUDAKCAN is for the temperatures gathered via the CAN BUS.

In RUDAKA and RUDAKB the columns of number are c, b, and a in

Value = ax^2+bx+c where raw counts are x.

In RUDAKCAN the numbers are a, b, c, d, e, f in

Temp = $ax^5+bx^4+cx^3+dx^2+ex+f$ where raw counts are x.

CAN BUS temps are sent after the values listed in RUDAKA and RUDAKB only if CANsrstat 0. CANst40/50 is also sent only if CANsrstat 0. There are 16 CAN BUS temps if sent. ■

RUDAKA

0	10V Reg Temp	+95.793	-0.0359	+0.0	Deg. C
1	Mem Temp	+95.793	-0.0359	+0.0	Deg. C
2	10V Sw V	+0.0146	+0.0032	-0.00000008	Volts
3	10V Sw V B	+0.0146	+0.0032	-0.00000008	Volts
4	5V V B	-0.0212	+0.0021	-0.00000003	Volts
5	VCC I B	+0.0511	+0.0017	+0.0	Amps
6	VCC I	+0.0511	+0.0017	+0.0	Amps
7	5V V	-0.0212	+0.0021	-0.00000003	Volts
8	DSP I A side	+0.0511	+0.0017	+0.0	Amps
9	DSP I B side	+0.0511	+0.0017	+0.0	Amps
A	DSP U14 Temp	+95.793	-0.0359	+0.0	Deg. C
B	DSP U30 Temp	+95.793	-0.0359	+0.0	Deg. C
C	DSP U34 Temp	+95.793	-0.0359	+0.0	Deg. C
D	Top sideA Tmp	+95.793	-0.0359	+0.0	Deg. C
E	VReg A Temp	+95.793	-0.0359	+0.0	Deg. C
F	DSP U45 Temp	+95.793	-0.0359	+0.0	Deg. C
10	DSP U47 Temp	+95.793	-0.0359	+0.0	Deg. C
11	DSP U50 Temp	+95.793	-0.0359	+0.0	Deg. C
12	DSP U13 Temp	+95.793	-0.0359	+0.0	Deg. C
13	DSP U25 Temp	+95.793	-0.0359	+0.0	Deg. C
14	DSP U33 Temp	+95.793	-0.0359	+0.0	Deg. C
15	VReg B Temp	+95.793	-0.0359	+0.0	Deg. C
16	Top sideB Tmp	+95.793	-0.0359	+0.0	Deg. C
17	DSP U49 Temp	+95.793	-0.0359	+0.0	Deg. C
18	DSP U51 Temp	+95.793	-0.0359	+0.0	Deg. C
19	DSP U36 Temp	+95.793	-0.0359	+0.0	Deg. C
1A	Accel X	+0.0	+1.0	+0.0	Counts
1B	Accel Y	+0.0	+1.0	+0.0	Counts
1C	Accel Z	+0.0	+1.0	+0.0	Counts
1D	WODF state	+0.0	+1.0	+0.0	Counts
1E	Digi status	+0.0	+1.0	+0.0	Counts
1F	PHT Time	+0.0	+1.0	+0.0	Seconds
20	Unused	+0.0	+1.0	+0.0	Seconds
21	DSP RX select	+0.0	+1.0	+0.0	Counts
22	153k6 RX sel	+0.0	+1.0	+0.0	Counts
23	IHU pass stat	+0.0	+1.0	+0.0	Counts
24	TLM Ratio	+0.0	+1.0	+0.0	Counts
25	Msg 2 Ratio	+0.0	+1.0	+0.0	Counts
26	Text Msg Ratio	+0.0	+1.0	+0.0	Counts
27	9k6 0 out lvl	+0.0	+1.0	+0.0	Counts
28	9k6 1 out lvl	+0.0	+1.0	+0.0	Counts
29	153k6 out lvl	+0.0	+1.0	+0.0	Counts
2A	IHU A cnt	+0.0	+1.0	+0.0	Counts
2B	IHU othcnt	+0.0	+1.0	+0.0	Counts
2C	Unused	+0.0	+1.0	+0.0	Counts
2D	CANsrstat	+0.0	+1.0	+0.0	Counts
2E	CANst40/50	+0.0	+1.0	+0.0	Counts

Figure 1a. RUDCOEFX - RUDAKA

RUDAKCANA

2F	VTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
30	UTXSink2	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
31	UTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
32	UTxPip12	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
33	STx1Sink3	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
34	Unused	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
35	STx1Pipe4	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
36	HtPipe3Bay3	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
37	HtPipe1+X+Y	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
38	HtPip13Bay6	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
39	HtPipe4+X+Y	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
3A	XTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
3B	BCR2HeatSink	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
3C	Unused	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
3D	VTxSink1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
3E	XTxTWSink	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C

RUDAKB

0	10V Reg Temp	+95.793	-0.0359	+0.0	Deg. C
1	Mem Temp	+95.793	-0.0359	+0.0	Deg. C
2	10V Swchd V	+0.0146	+0.0032	-0.00000008	Volts
3	10V Sw V A	+0.0146	+0.0032	-0.00000008	Volts
4	5V V A	-0.0212	+0.0021	-0.00000003	Volts
5	VCC I A	+0.0511	+0.0017	+0.0	Amps
6	VCC I	+0.0511	+0.0017	+0.0	Amps
7	5V V	-0.0212	+0.0021	-0.00000003	Volts
8	WODF state	+0.0	+1.0	+0.0	Counts
9	Digi status	+0.0	+1.0	+0.0	Counts
A	PHT Time	+0.0	+1.0	+0.0	Seconds
B	Unused	+0.0	+1.0	+0.0	Seconds
C	DSP RX select	+0.0	+1.0	+0.0	Counts
D	153k6 RX sel	+0.0	+1.0	+0.0	Counts
E	IHU pass stat	+0.0	+1.0	+0.0	Counts
F	TLM Ratio	+0.0	+1.0	+0.0	Counts
10	Msg 2 Ratio	+0.0	+1.0	+0.0	Counts
11	Text Msg Ratio	+0.0	+1.0	+0.0	Counts
12	9k6 0 out lvl	+0.0	+1.0	+0.0	Counts
13	9k6 1 out lvl	+0.0	+1.0	+0.0	Counts
14	153k6 out lvl	+0.0	+1.0	+0.0	Counts
15	IHU A cnt	+0.0	+1.0	+0.0	Counts
16	IHU othcnt	+0.0	+1.0	+0.0	Counts
17	Unused	+0.0	+1.0	+0.0	Counts
18	CANsvrstat	+0.0	+1.0	+0.0	Counts
19	CANst40/50	+0.0	+1.0	+0.0	Counts

RUDAKCANB

1A	VTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
1B	UTXSink2	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
1C	UTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
1D	UTxPip12	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
1E	STx1Sink3	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
1F	Unused	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
20	STx1Pipe4	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
21	HtPipe3Bay3	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
22	HtPipe1+X+Y	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
23	HtPip13Bay6	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
24	HtPipe4+X+Y	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
25	XTxPipe1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
26	BCR2HeatSink	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
27	Unused	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C
28	VTxSink1	-2.35539910e-012	6.30739610e-09	-6.4495019e-06	0.003175981	-0.91266367	170.25368 Deg. C

Figure 1b. RUDCOEFX: RUDAKCANA, RUDAKB, and RUDAKCANB.

An Overview of the Electronic Modules on the AMSAT Phase 3D Satellite

Peter Guelzow, DB2OS

Translated by John Bubbers, W1GYD

Editor's Note: This article originally appeared in the September/November issue of the AMSAT DL Journal. It was published shortly after Phase 3D had successfully completed all of its tests and as a result there were no significant changes in the hardware configuration. The photographs representing figures 3-8 were taken in October 2000 during Phase 3D integration in Kourou, French Guiana.

The exploded drawing in Figure 1 shows the spatial relationships of the satellite's mechanical and electronic components. In the core of Phase 3D are the tanks and the rocket propulsion motors. Additionally, located beneath the tanks are the three reaction wheels for active, three axis orientation control. The three axis reaction wheels direct the antennas toward the earth and orient the solar cells toward the sun during complete orbits. In the vicinity of the earth, the magnetic coils (magnetic stabilizer) are added to adjust the orientation and to relieve the torque moments of the reaction wheels. Additionally the main and auxiliary batteries are attached to the transverse walls.

In the six module bays (Figures 2a and 2b) are the satellite's complete electronics. The table shows the list of the modules along with their constructors and identification in the satellite. The module bays are numbered 1 through 6.

Bay 1 (Figure 3)

On the upper right hand side behind a protective cover are the controls and vents for both rocket motors. To the left is the attendant electronics (LIU). In the lower row, from left to right, are the cosmic radiation measurement experiment (CEDEX), the sensor electronics (SEU), which processes the outputs of the various sensors, and one of the three battery regulators.

Bay 2 (Figure 4)

Toward the top, and later to be aimed at the earth, are located the three cameras: both of the SCOPE cameras and the YACE camera that was added later and with which the separation of the satellite will be monitored. This camera is connected to the second, new on-board computer (YAHU-2, IHU-2),

which is mounted one level lower. On the above right the various modules for the S-band transmitter are located on four levels (exciter, PA, HELAPS). On the bottom of this bay are the receiver modules for the L-band, the S-band, C-band, and the HF receiver.

Bay 3 (Figure 5)

In the adjacent bay are the S-band transmitter, the receivers for VHF and UHF (2 meter and 70 cm), the switching unit for the antenna relays (RFRU), the UHF 70-cm-transmitter, and the 2 meter transmitter (VHF).

Bay 4 (Figure 6)

The K-band 24 GHz transmitter is located at the upper left, and immediately next to it is the power supply unit which provides important, regulated operating voltages. In the lower row is the unit responsible for the deployment of the solar panels (Array Release Unit), the IF matrix which connects the various transmitters and receivers to one another, above that LEILA, and the electronics for the ATOS power unit (EPU).

Bay 5 (Figure 7)

Half of this bay is occupied by the X-band 10 GHz transmitter. Completely to the left are both horns which project into the bay in which the travelling wave tube is located which delivers 60 Watts output. In the upper center is the HF monitoring experiment, which measures space contamination with terrestrial high frequency in the shortwave region.

On the upper right, parts of the GPS experiment can be seen, with which the attitude and position of the satellite will be determined in space. Beneath it is a battery charging regulator.

Bay 6 (Figure 8)

Immediately adjacent to the GPS modules, in bay 5, are the related receivers. On the right hand side are the electronics, which process the signals from the many sun sensors (ASSP). Fully right, the L-band receiver 1 with hardware for decoding and evaluating the commands (CMDA/CMDDD) can be seen. Below, from left to right, are the

battery charging regulator 1, RUDAK with related modems and the on-board computer (IHU) with the input/output module (I/O) for the multiple data and control signals.

Antennas

The numerous directional antennas for the various bands can be seen in the drawings in Figure 9. Along the edge of the satellite structure the sensors are located for determining attitude. The omni-sun-sensors determine the coarse orientation in space. Immediately after the launch Phase 3D should circle the earth in a definite attitude. It will operate as a spin stabilized satellite, as in the familiar AO-10 and AO-13. The earth sensor 2 and sun sensor 2 are particularly set for this phase, and they mimic the previous satellites. Once Phase 3D has achieved its final orbital path and the sun sails have been deployed, then the antenna plane will be aimed at the earth and the solar panels at the sun. The earth sensor 1 and the *stable mode* sun sensor are important for the fine tuning of the satellite's attitude.

On the underside are more sun sensors and four more GPS-antennas for those orbital paths during which Phase 3D is inside the GPS orbital path. Additionally, the omni-directional antennas for 2 meters, 70 cm and 23 cm are located nearly in the center. Communications can be conducted on these antennas at perigee when the gain of the antennas on the upper side becomes to great and the antenna lobe is too narrow to illuminate the entire earth. The ATOS drive for path correction in the operation phase of Phase 3D is located not quite in the center. In order to not produce a turning moment during the ignition phase of the satellite, to compensate it is mounted slightly inclined.

Solar Panels

The energy for the complete satellite is derived from the six solar cell arrays. Two panels, 1 and 6, have a smaller usable area. This assures a thermal balance of the satellite and prevents overheating. On the other hand, the deployable modules use the complete available area.

A complete overview of all of Phase 3D's modules is provided as Figure 10. ■

AMSAT P3-D International Satellite

3189 C9 06.05.99

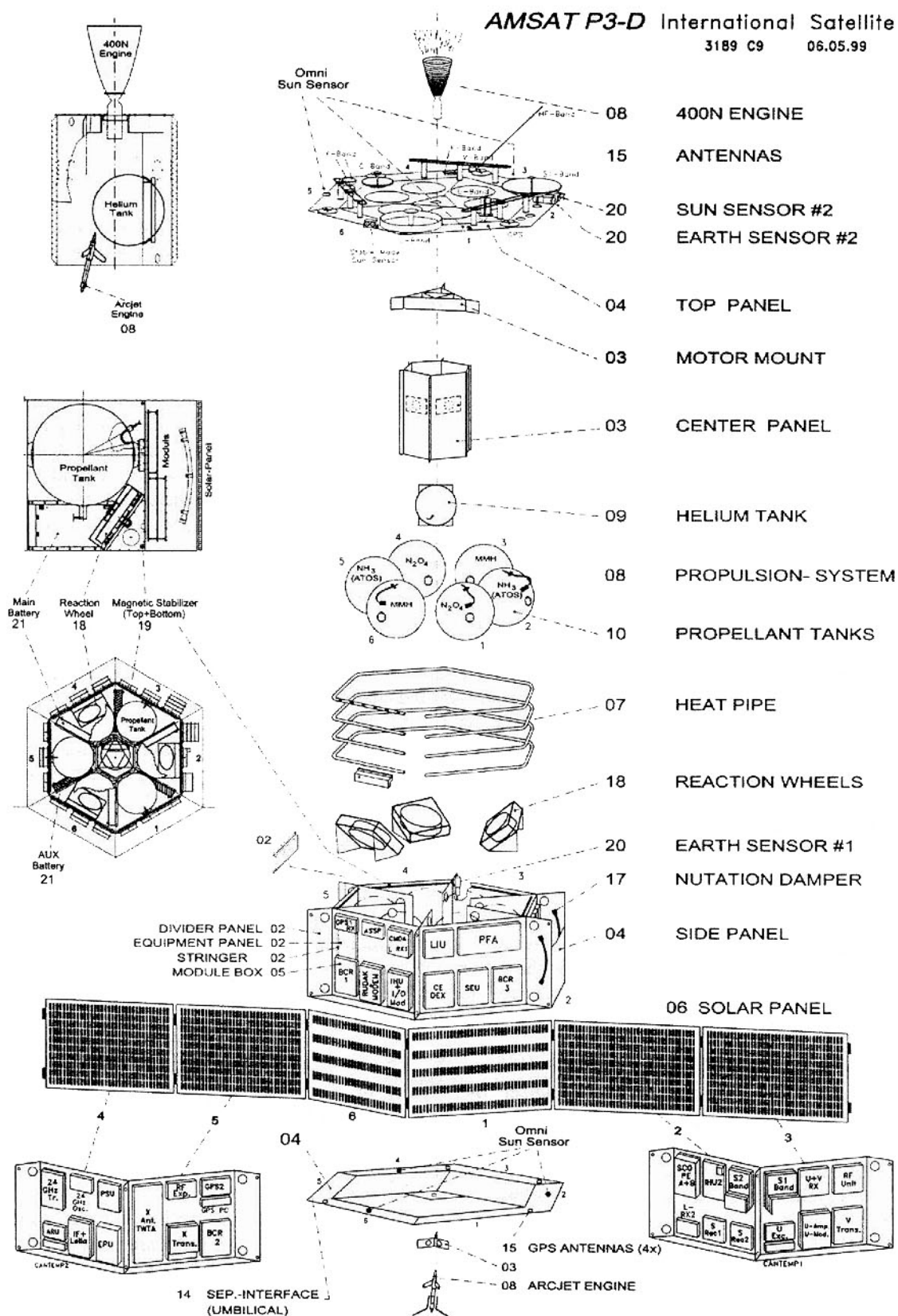
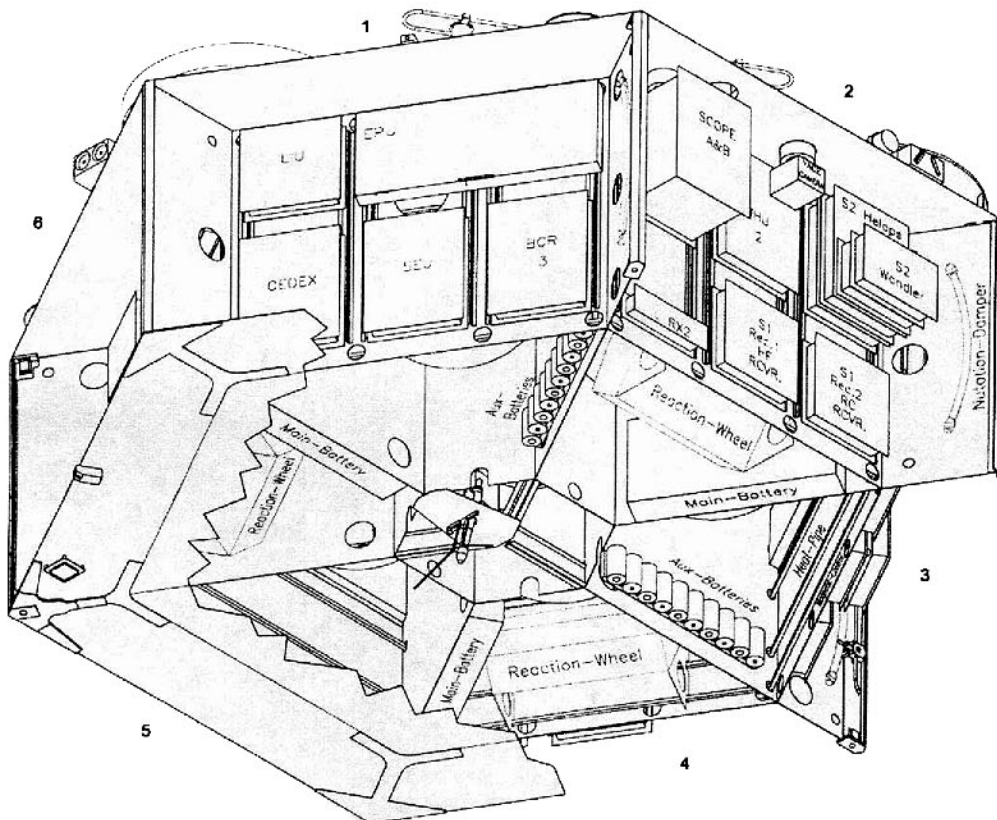
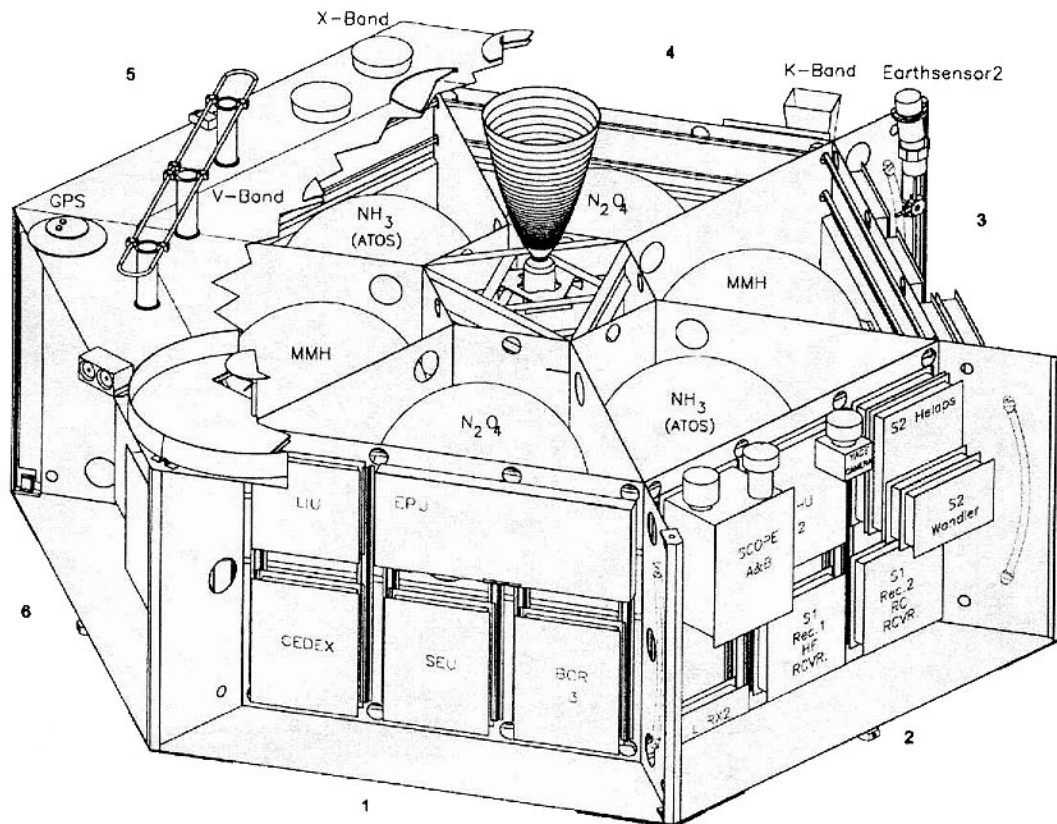


Figure 1. An exploded view of the Phase 3D satellite.



Figures 2. and 2b. Assembled components of the Phase 3D spacecraft.

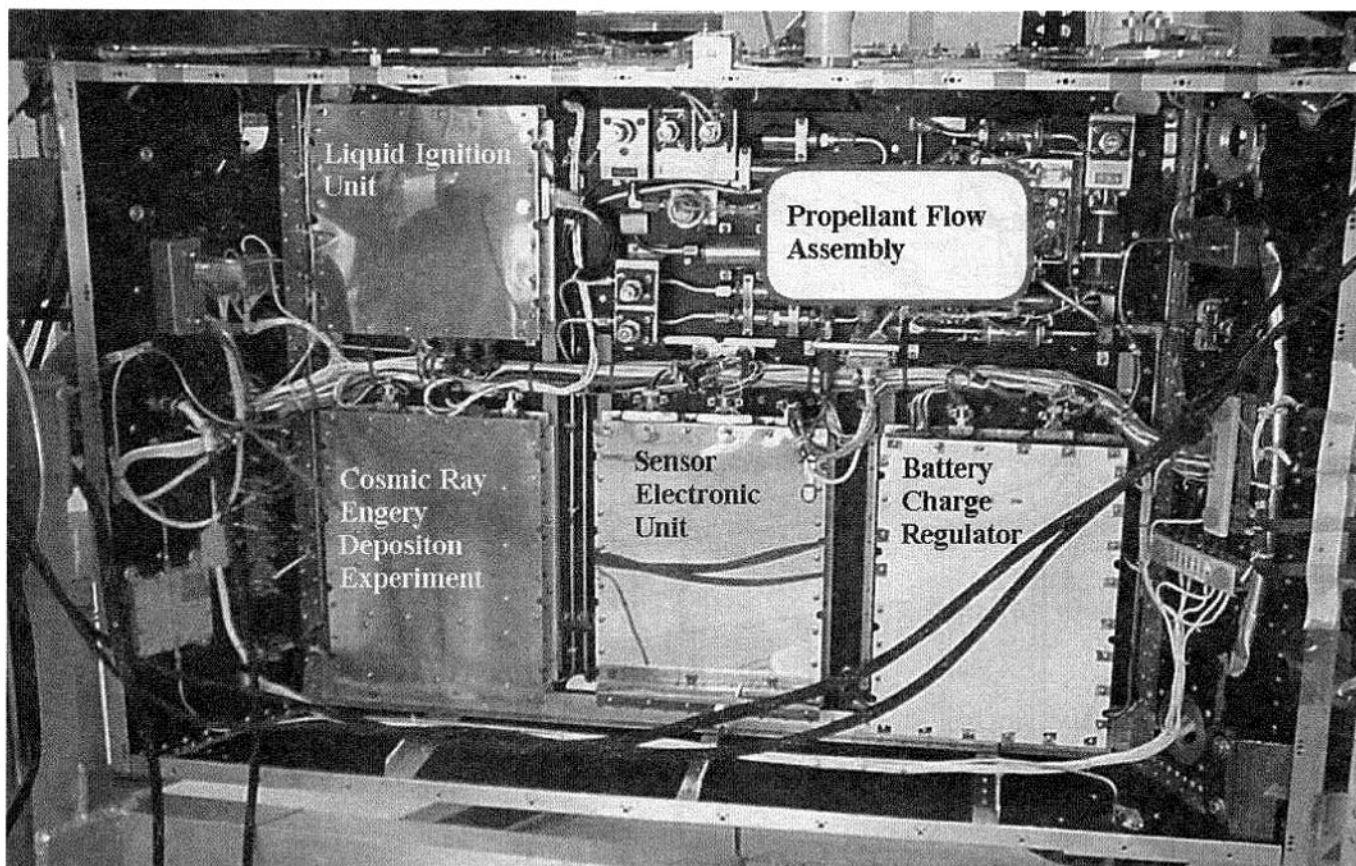


Figure 3. Location of modules in Bay 1.

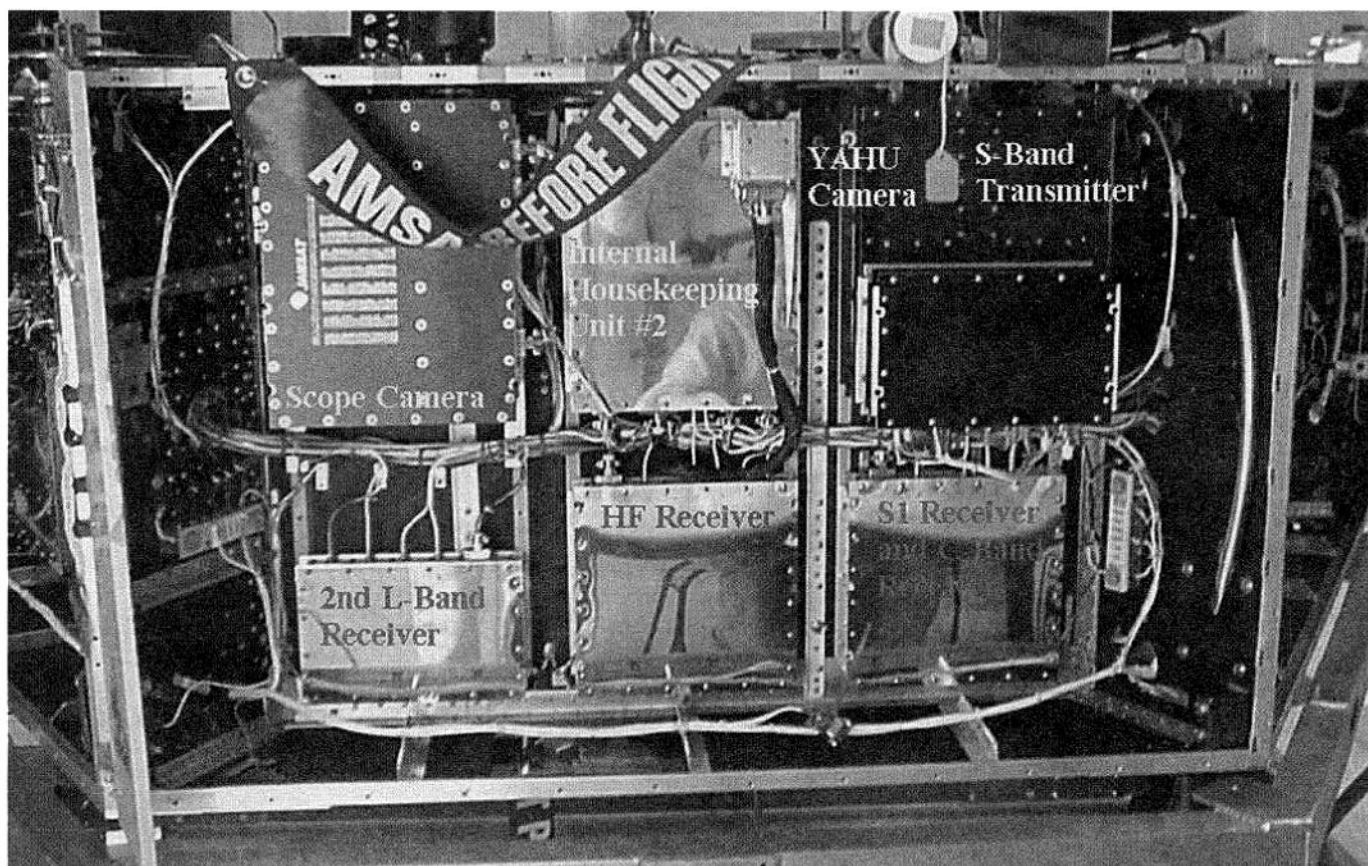


Figure 4. Location of modules in Bay 2.

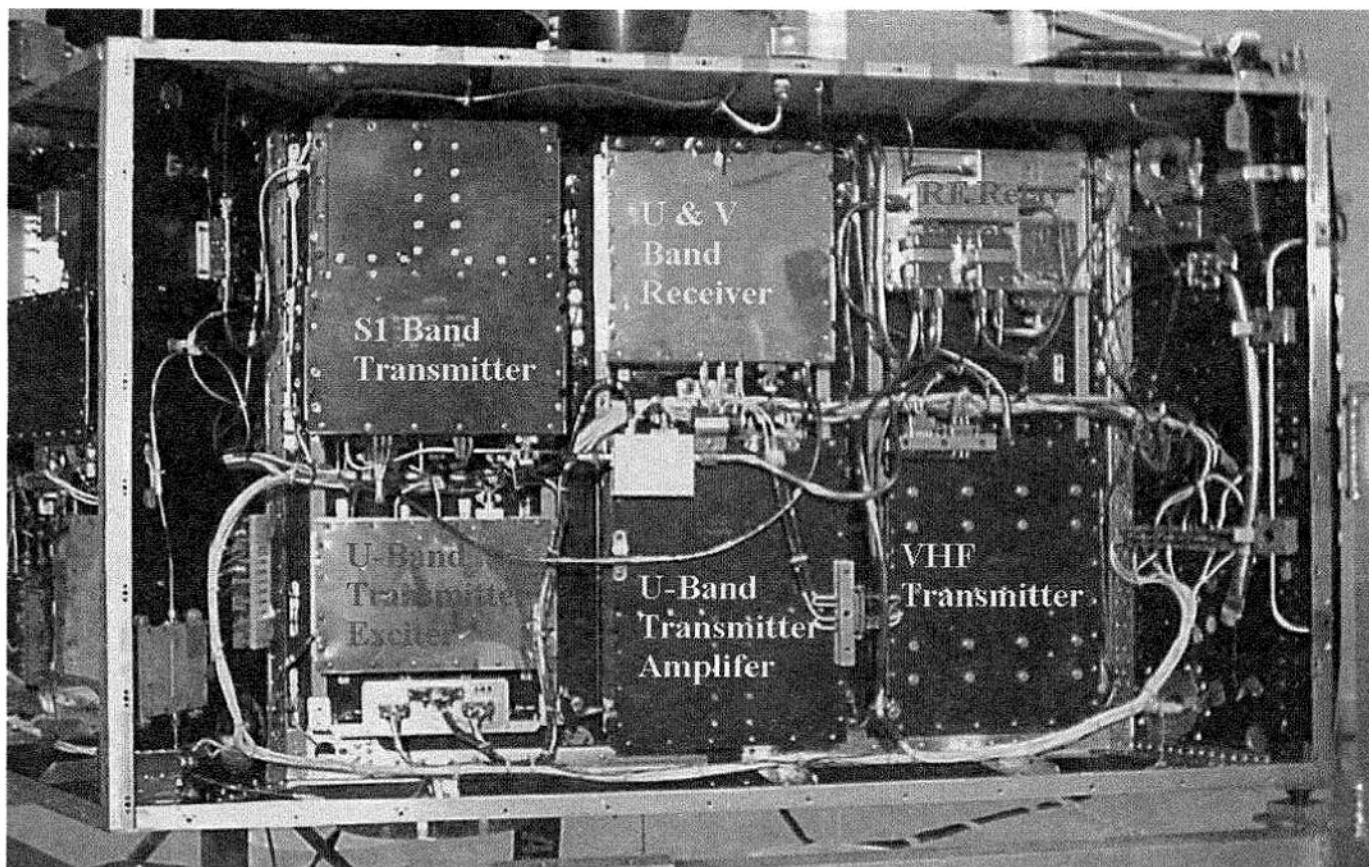


Figure 5. Location of modules in Bay 3.

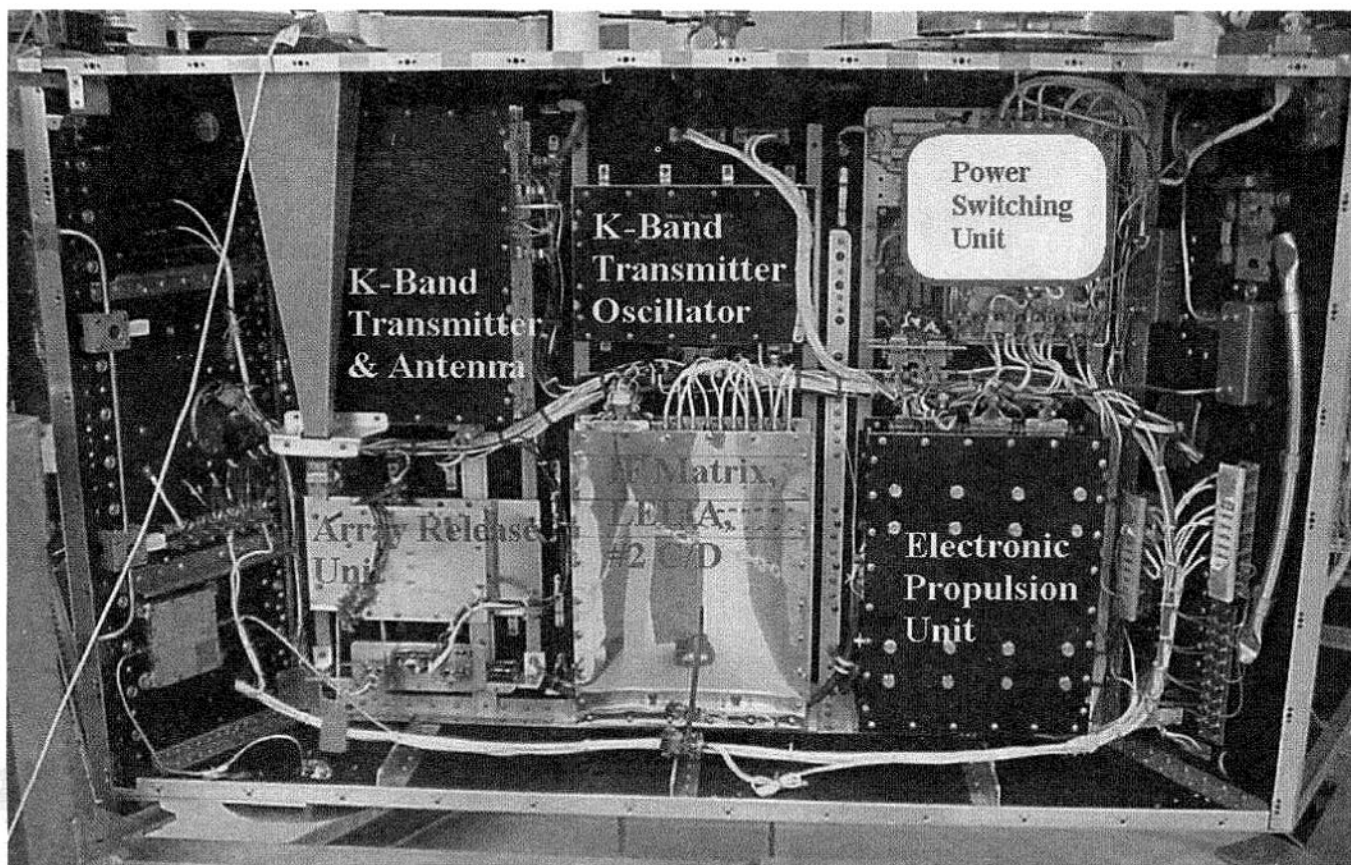


Figure 6. Location of modules in Bay 4.

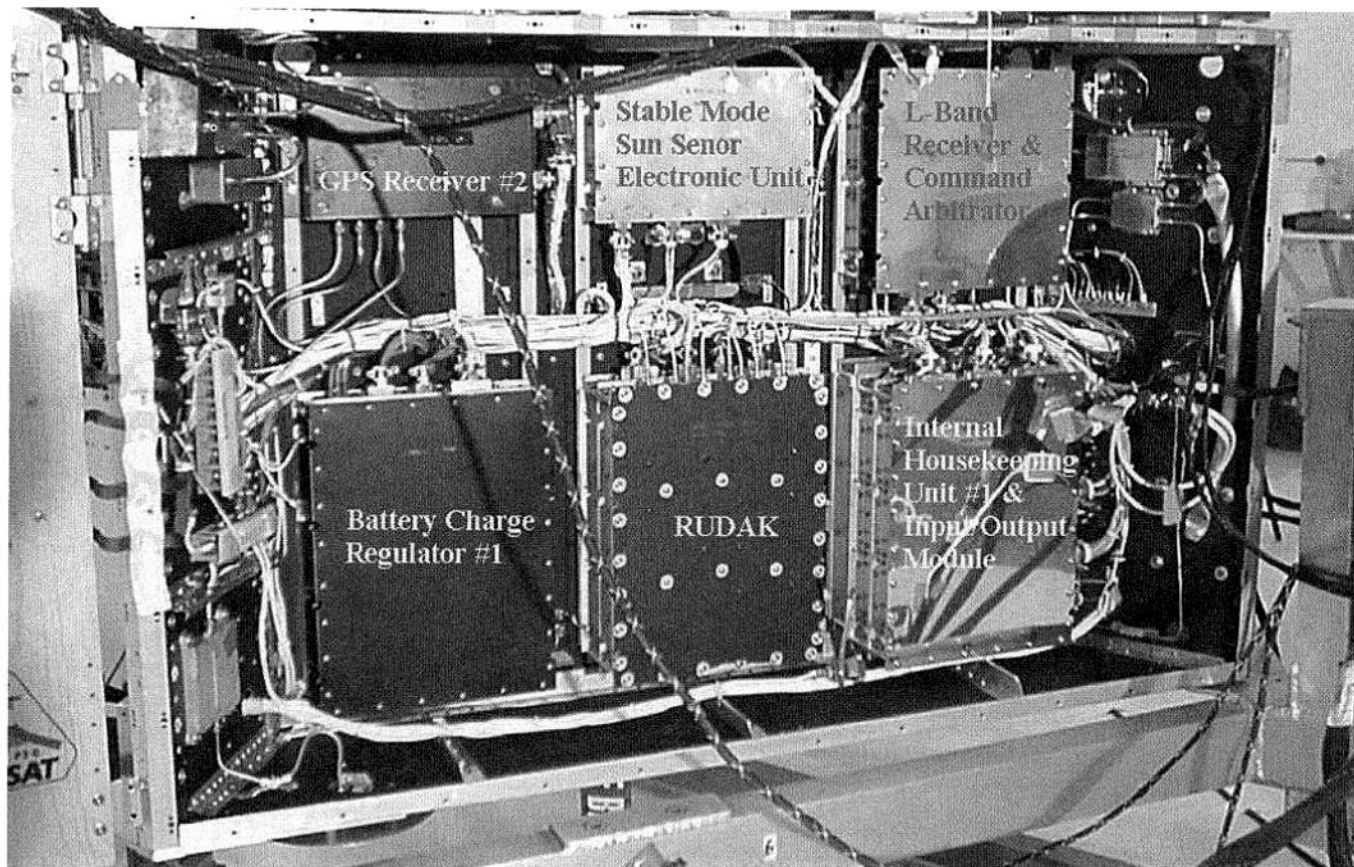


Figure 7. Location of modules in Bay 5.

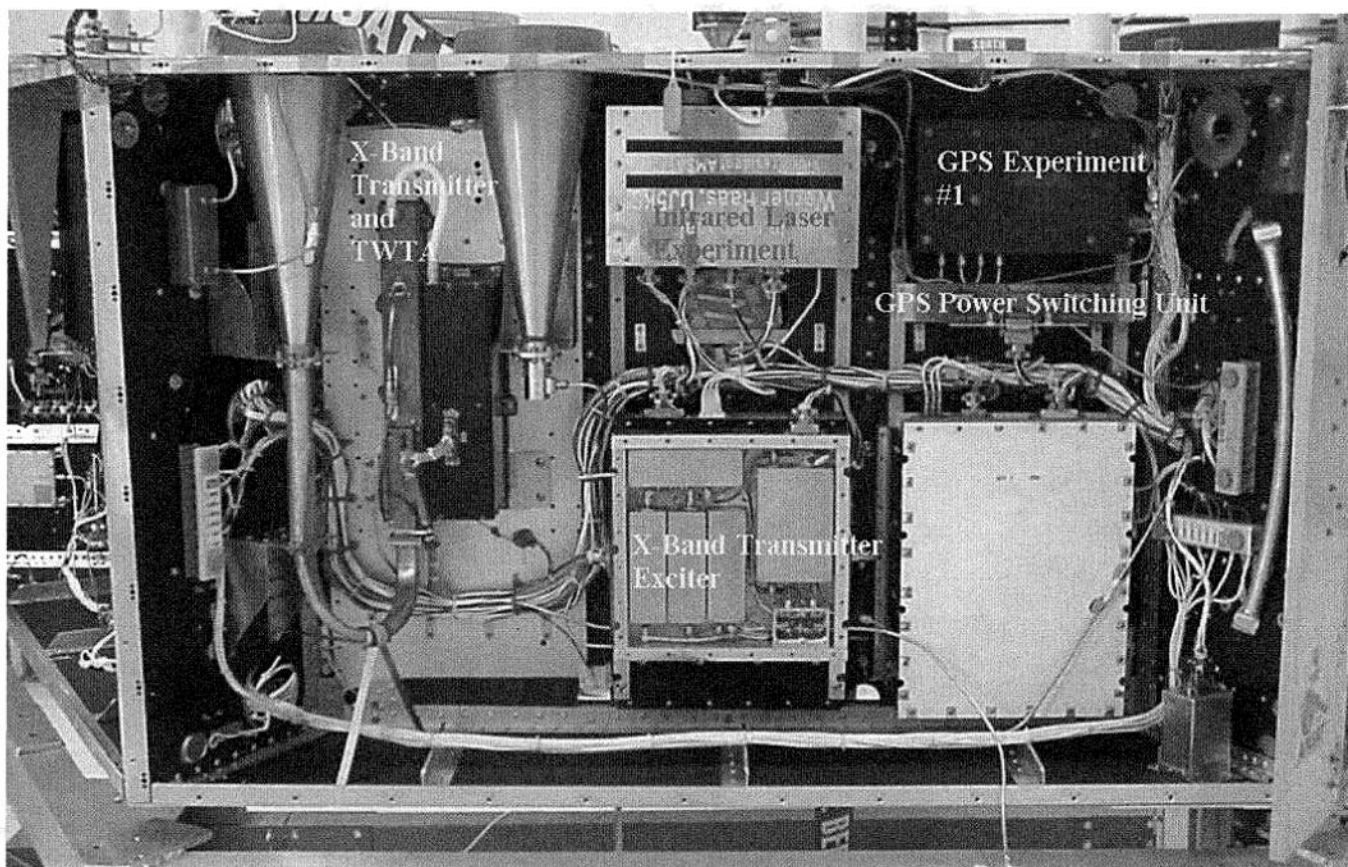


Figure 8. Location of modules in Bay 6.

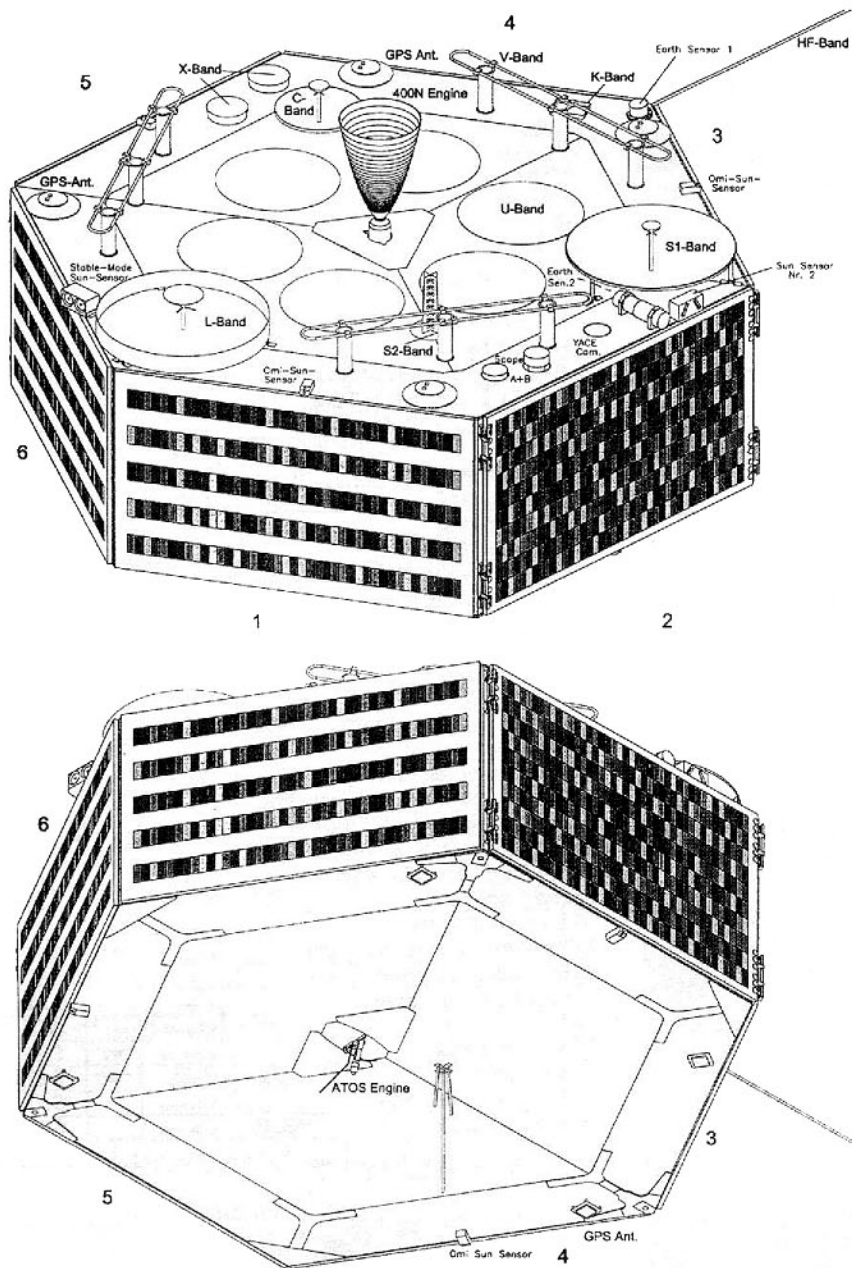
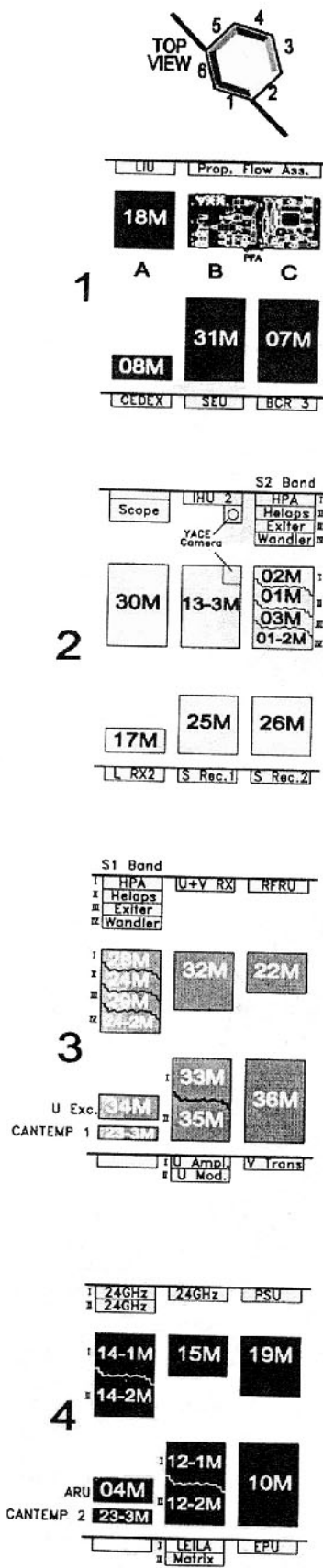


Figure 9. Location of antennas on Phase 3D.



P3-D-Module-Overview

\Module01.dwg 12.04.99

S2 Band Transm. Pow. Amplifier (HPA)	K. Brenndörfer	2 C1 ₁	02	M
S2 Band Helaps Modulator	W. Haas	2 C1 ₂	01	M
S2 Band Transmitter Exciter	Freddy de G.	2 C1 ₃	03	M
S2 Zusatz-Wandler für Helaps Modulator	W. Haas	2 C1 ₄	01-2	M
Array Release Unit (ARU)	R. Leon	4 A2	04	M
BCR 1	A. Geschwindt	6 A2	05	M
BCR 2	A. Geschwindt	5 C2	06	M
BCR 3	A. Geschwindt	1 C2	07	M
Cedex Experiment	Craig Underwood	1 A2	08	M
CMDA Unit CMDArbitration	L. Mc Fadin	6 C1 ₁	09-1	M
CMDA Unit PSKDEM 2	W. Haas		09-2	M
Electronic Propulsion Unit (EPU)	C. Green, K. Müller, W. Haas	4 C2	10	M
GPS RX1	B. Garben, B. Garben, B. Garben, B. Garben	6 A1	11-1	M
GPS RX2	B. Garben, B. Garben, B. Garben, B. Garben	5 C1	11-2	M
GPS Power Controller	C. Green, L. Johnson	5 C1	11-3	M
Leila	M. Völmir	4 B2 ₁	12-1	M
IF Matrix	M. Völmir	4 B2 ₂	12-2	M
IHU Computer	C. Green, P. Gilzow, L. Johnson	6 C2 ₁	13-1	M
I/O Modul	C. Green, P. Gilzow, L. Johnson	6 C2 ₂	13-2	M
IHU Computer 2 (YAHU)	C. Green, P. Gilzow, L. Johnson, J. Miller	2 B1 ₁	13-3	M
YACE Camera	P. Gilzow	2 B1 ₂	13-4	M
K Band 24 GHz Transmitter Teil 1	D. Orban	4 A1 ₁	14-1	M
K Band 24 GHz Transmitter Teil 2	D. Orban	4 A1 ₂	14-2	M
K Band 24 GHz TX Oscillator	D. Orban	4 B1	15	M
PSKDEM 1	W. Haas	6 C1 ₂	16-1	M
L Band Receiver 1	M. Kossal		16-2	M
L Band Receiver 2	M. Kossal, W. Haas	2 A2	17	M
Liquid Ignition Unit (LIU)	R. Leon	1 A1	18	M
Power Supply Unit	L. Mc Fadin	4 C1	19	M
Propellant Flow Assembly (look 08 mechanic)	S. Daniels	1 B1		
RF Monitor Experiment	A. Geschwindt	5 B1	21	M
RF Relay Unit (RFRU)	L. Mc Fadin	3 C1	22	M
RUDAK	Green, Gilzow, L. Johnson	6 B2 ₁	23-1	M
RUDAK MODEM	Green, Gilzow, L. Johnson	6 B2 ₂	23-2	M
CAN-LAN (CAN TEMP1+2)	Green, Gilzow, L. Johnson	3A2 / 4A2	23-3	M
S1 Band Transm. Pow. Amplifier (HPA)	D. Orban	3 A1 ₁	28	M
S1 Band Helaps Modulator	W. Haas	3 A1 ₂	24	M
S1 Band Transmitter Exciter	Freddy de G.	3 A1 ₃	29	M
S1 Band Zusatz-Wandler für Helaps Mod.	W. Haas	3 A1 ₄	24-2	M
S1 Band Receiver 1 HF Band Rec.	M. Völmir	2 B2	25	M
S1 Band Receiver 2 C Band Rec.	M. Völmir	2 C2	26	M
Scope A & B Camera Experiment	M. Nakajima	2 A1	30	M
Sensor Electronics Unit (SEU)	W. Loeber, J. Mc Donnell	1 B2	31	M
U & V Band Receivers	Freddy de G.	3 B1	32	M
U Band Transmitter Power Amplifier	K. Hupfer	3 B2 ₁	33	M
U Band Helaps Modulator	W. Haas	3 B2 ₂	35	M
U Band Transmitter Exciter	W. Haas	3 A2	34	M
V Band Transmitter	M. Dorsett	3 C2	36	M
X Band Transmitter	J. Pullanen	5 B2 ₁	37	M
X Band Exciter	M. Fletcher/J. Pullanen	5 B2 ₂	37-2	M
X Band TWTA Power Supply	M. Fletcher/J. Pullanen	5 A	37-3	M
Analog Sun Sensor Processor (ASSP)	L. Mc Fadin	6 B1	39	M

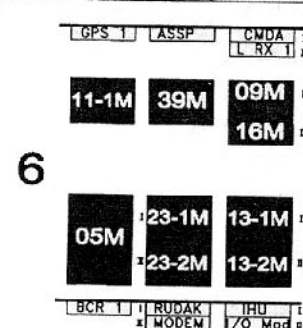
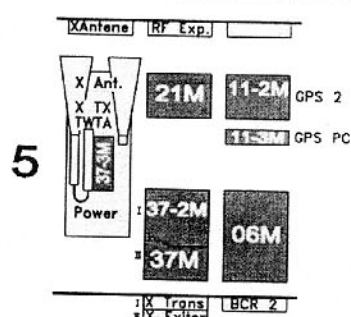
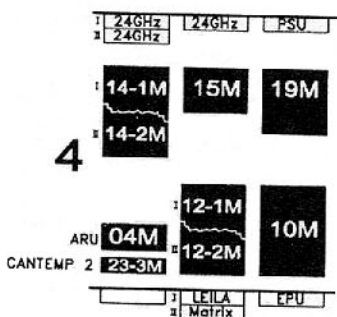


Figure 10. An overview of Phase 3D modules.

Tuning Up! - Making Your Phase 3D Station Active

Franz J. Bellen, DJ1YQ

Translation by: John J. Bubbers, W1GYD

Editor's Note: This article originally appeared in the the AMSAT DL Journal. Several North American sources equipment references have been added.

First Step: Using the New Bands on the Downlink

For a long time many ham operators as well as commercial equipment developers have been in a start mode while planning to acquire new equipment for Phase 3D, or to develop new ones. Previously, Amateur Radio satellite communications concentrated on the 2 meter and 70 cm bands, but now Phase 3D opens a door to a new world of microwaves. This presentation will show that these bands can be opened to all sorts of goals and pocketbooks.

Band Combination Choices

AMSAT Phase 3D is the Amateur Radio satellite with the largest number of usable frequency bands. Nine receivers on seven bands are available on the uplink, and the downlink is fed by a total of six transmitters on five bands [1]. This means that there are theoretically 32 possible combinations. In practice, not all of these possibilities will be used. For example, the combination of a 21 MHz receiver and a 24 GHz transmitter doesn't make much sense.

No clairvoyant talents are needed to make interesting band combination forecasts, since there are already many band combinations, which are already based on physical reasons. Ultimately, members of a Phase 3D project board will make the final decisions as to which modes will be activated and when. The basis for decision-making will be the safety and

maintenance of the satellite, the energy budget, technical parameters and the users' preferences. Certainly the main operating bands in the satellite's early years will be those from 2 m to 13 cm bands.

Thankfully, the following combinations are very practical and technically feasible:

- Downlink: 70 cm (U); Uplink: 23 cm (L) and 2 m (V) parallel
- Downlink: 13 cm (S); Uplink: 70 cm (U) and 23 cm (L) parallel

The first combination is favorable when the Phase 3D is not fully at apogee. The antennas of these bands have a large viewing angle and will fully cover the earth on either side of the apogee period. All of those who have the equipment used for working AO-10 and AO-13 can begin operating on this mode immediately. And for the band combination 70cm/2m (U/V) it is mathematically possible to operate mobile without directional antennas! The use of the 2 meter band has, however, one great disadvantage since there are many PACSAT-uplinks which are in the passband and could interfere severely with those radio satellite communications.

The second combination would be the first choice in the hours surrounding the apogee period. There are bands in use with potentially less interference on the downlink as well as on the uplink. By using the parallel 70 cm uplink many countries in which transmission in the upper part of the 70 cm band is not permitted will be able to participate. And technically, for example, a downconverter from 13 cm to 2 m is simpler and less expensive than a microwave uplink.

Operating Parameters

The physical operating parameters for the path lengths were extensively described in [2]. The following sample configurations are for ground operation at the apogee on the four main bands. Accordingly, when the satellite is close to the earth, there is less power required.

- **145 MHz Uplink:** 10 Watts of transmitter power with a 7 element crossed Yagi with about 10 dBi gain will give a S/N ratio of about 23 dB for SSB at the apogee. With 50 Watts and a crossed dipole above a reflecting sur-

Congratulations from AMSAT-UK

The Committee and Members of AMSAT-UK wish to thank and congratulate all those who have in any way contributed to the success of the magnificent and ambitious Phase 3D project.

We feel privileged to have been able to offer support and we thank the other Amsat organisations and the Radio Society of Great Britain who have in turn supported us, together contributing over US\$400,000 to the Phase 3D project to date.

Our heartfelt thanks to the dedicated team who have turned the dream of Phase 3D into reality

Amsat-UK

December 2000

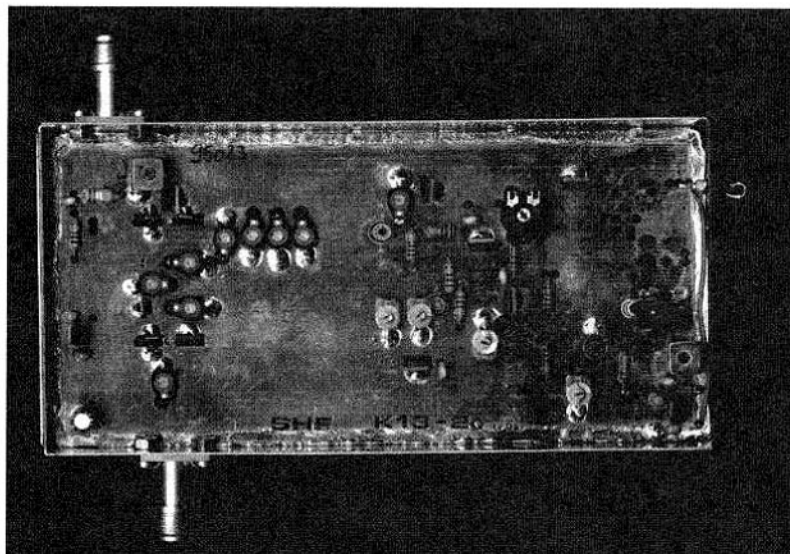


Figure 1. The SHF-Electronic SHF K13 SSB Converter.



www.amsat.org/amsat-sm

AMSAT-SM congratulates and thanks the P3D project team for its ability to successfully realize this fantastic international project

face (such as an automobile roof) the same result can be achieved.

- **435 MHz Uplink:** Thanks to the satellite's higher antenna gain on this band, approximately the same equipment line-up is called for as on 2 m. It is possible to operate packet at 9600 bps/FSK with current AO-10 and AO-13 set ups.
- **1268 MHz Uplink:** For good results, an effective radiated power of 200 Watts must be available. This would be, for instance, 10 W (Mitsubishi 23-cm PA Module) using a helical antenna with 8 to 12 turns (length only 70 cm!) or 5 Watts with a 60 cm parabolic reflector or about 100 W with a HB9CV. The experiences on AO-10 and AO-13 have indeed shown that on 23 cm one should really have an additional 3 dB in reserve. All indicated power requirements are for SSB, while for 9k6 packet radio an additional 6 dB should be added, because of the increased bandwidth.
- **435 MHz Downlink:** Good SSB contacts are possible with a 3-element crossed Yagi and a low noise receiver pre-amplifier at the antenna. Packet radio is possible with a 12-element Yagi antenna and a pre-amplifier.
- **2400 MHz Downlink:** Good results are possible using a 60 cm parabolic reflector and a pre-amplifier with a noise figure of 1.5 dB at the driven element. If a smaller antenna is wanted, one can receive good SSB signals using an especially low noise pre-amplifier (.9 dB NF) with a 12 turn helical antenna (45 cm length).

If the concern is for small antennas and low transmitter power, then nothing beats Phase 3D's 23 cm and the 13 cm bands.

Transceivers

There are very few all-mode transceivers available for these high bands. The widely available and distributed FT-736R, which has a 23 cm retro-fit module available, is an example. The earlier UHF flagship of ICOM, the IC-970, could similarly be retro-fitted, and according to the advertising brochure, it claimed it could also be retro-fitted with a 13 cm receiver module. There were no known operating reports from users. Aside from the

multi band transceivers, separate units are quite appropriate for each band.

The operating practice of most radio amateurs, especially if they are just beginning and can only obtain *off the shelf* systems for 2m and 70 cm, will be to translate the microwave bands using a converter and transverter. Using this configuration has the great advantage that the translators can be located close to the antenna and thereby reduce large cable losses. A smaller coax cable will then be adequate to bring the higher level intermediate frequency signal down into the shack.

Converter from Top Down

For future optimal band combinations, the first expansion step would be a down-converter from 2400 MHz to an intermediate frequency (IF) of 432 MHz or 144 MHz. This presents a dilemma, which was previously described in [3]. With 432 MHz as the IF, this band is eliminated as an uplink. Even with two transceivers for 70 cm there would probably be cross talk from the transmitter at the intermediate frequency. At an intermediate frequency of 144 MHz there is the U/S mode combination, which would be blocked due to a subsequent frequency translation from 144 MHz to 1268 MHz for the 23 cm uplink in mode L/S. That's all right for those who can operate on three bands or have an equivalent number of transceivers. The 28 MHz or the unused transmitter part of the 50 MHz band could be considered for the output frequency for a 23 cm uplink mixer. Naturally, one could also buy and mount two S-band converters for 13 cm to 2 m and 70 cm. Then everything would work: V/U, U/V, L/U, U/L, L/S, U/S and still higher microwave bands. The IF problem can also be avoided for these bands with home built transceivers, as was described in [7].

No one needs to be afraid of 2400 MHz. Everything is available from simple construction descriptions to complete systems (plug-n-play). The investments are within the limits of what one paid for a good mast-mounted pre-amplifier for AO-10 and AO-13. Home construction enthusiasts will have a cost advantage price, but that is splitting hairs.

In the past few years there were three home construction projects presented for 13 cm converters [4, 5, 6] in the *AMSAT-DL Journal*. Beyond that, construction articles for converters and preamplifiers have

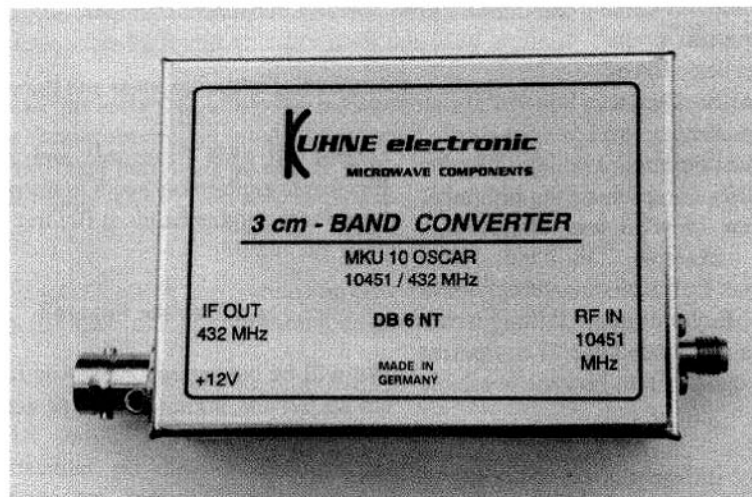


Figure 2. This is Kuhne Electronic's 10.452 GHz to 432 MHz Converter

Phase 3D CONGRATULATIONS

New Zealand amateurs salute all involved in the
Phase 3D project.

AMSAT-ZL, a young group, continues the tradition of providing a local New Zealand ground control station for the Phase 3 projects. **AMSAT-ZL** proudly provides services in support and encouragement of local amateur involvement in amateur radio satellites.

Internationally, **AMSAT-ZL**, in addition to financial assistance, provided vital components for the Phase 3D International Satellite. **AMSAT-ZL** looks to increasingly involve New Zealand amateurs in future projects.

AMSAT-ZL: Supporting the Amateur Satellite Service.

AMSAT-ZL: jpsl@ihug.co.nz 20 First View Avenue, Beachlands, Auckland, New Zealand

appeared in other radio amateur publications for many years (*QST*, *CQ-DL*). There are pre-amplifier kits available for between \$270 and \$325 from Eisch-Kasfka-Electronic, and GIGA-TECH will introduce a whole series of low noise preamplifiers in the coming year.

On the commercial scene there is a larger selection of finished units for 13 cm. Table 1 presents an overview of the respective systems. The list is not necessarily comprehensive, but rather presents a view of what was offered to a visitor, for example, at the 1999 *UKW-Tagung* (Ultra Short-Wave Symposium). Beyond that, Dirk Fischer Elektronik has announced useful equipment for Phase 3D operating to become available in the future.

The large price differences are the result of different construction details. Coaxial relays, water-tight mast housings add to the price. But there are also technical differences. Noise figure and gain figures are two criteria. The IF image frequency suppression, the intermodulation ratio and the oscillator stability also influence the price. The latter is especially important for external mounting. If one wants to reset frequencies accurately and install automatic Doppler correction, for example, this is not feasible in the external, mast mounted environment without thermal

control. At SSB Electronic and at Kuhne Electronic exploratory work is already being done for the higher bands at 10 GHz and even 24 GHz.

And for the Future?

We will be concerning ourselves for the 23 cm uplink and higher as well as antennas in the next AMSAT-DL issue. At several suppliers there will be interesting new developments, to which we are naturally looking forward.

List of Suppliers

Dirk Fischer Elektronik, Neuer Graben 83, D-44139 Dortmund, www.dfe-online.de

Eisch-Kasfka-Electronic, Abt-Ulrich-Str. 16, D-89079 Ulm-Gögglingen, www.pacsat.demon.co.uk/eisch.htm

GIGA-TECH, Fischerstr. 8, D-68542 Heddeshheim, www.giga-tech.de

Jutta Kuhne Electronic, Birkenweg 15, D-95119 Naila/Hölle, www.db6nt.dom

SSB Electronic USA, 124 Cherrywood Drive, Mountaintop, PA 18707. Telephone: 570-868-5643. www.ssbusa.com

References

[1] P3-D Transponder Frequenz bandplan, *AMSAT-DL Journal* 4/98 S. 53

[2] Frank Sperber, DL6BN, Die Phase 3-D Transponderkombinationen aus Benutzersicht, *AMSAT-DL Journal* 2/95 S. 22

[3] Frank Sperber, DL6DBN, Phase 3-D Bodenstationen, Skriptum AMSAT-DL Symposium 1996

[4] Mirek Kasal, OK2AQK, Ein Mode-S-Konverter, *AMSAT-DL Journal* 4/93 S. 4

[5] Matjaz Vidmar, S53MV, Ein Front-End für den Satellitenempfang im 13-cm-Band, *AMSAT-DL Journal* 2/94 S. 21

[6] David Bowman, G0MRF, S-Band/70 cm Empfangskonverter für P3-D, *AMSAT-DL Journal* 2/97 S. 4

[7] Matjaz Vidmar, S53MV, SSB Transceiver für 23, 12, und 6 cm ohne Abgleich, Teil 1: *AMSAT-DL Journal* 3/97 S. 97, Teil 2: *AMSAT-DL Journal* 4/97 S. 23

[8] SSB Electronic USA, 124 Cherrywood Drive, Mountaintop, PA 18707 www.ssbusa.com (Also US distributor for Kuhne Electronic) ■

Manufacturer	Model Number	NF	Gain	Price	Comments
SHF-Elektronik	MVV2400-VOX, Mast Mounted Pre-amp.	1.5 dB	25 dB	450 DM	
SHF-Elektronik	VV2400, Pre Amplifier Module	1.5 dB	25 dB	150 DM	
SHF-Elektronik	K13-SSB, Converter	2.5 dB	24 dB	220 DM	2 m IF, LO Optional
Kuhne Electronic	MKU24 OSCAR, Converter	0.6 dB	26 dB	500 DM	2 m IF
Kuhne Electronic	MKU232, Preamplifier	0.7 dB	15 dB	220 DM	
Kuhne Electronic	MKU23G, Converter/Transverter	0.8 dB	20 dB	800 DM	Includes 1 W Trans
SSB-Electronic	UEK-3000SAT, Mast Mount Converter	0.7 dB	30 dB	700 DM	Select 2m/70 cm IF
SSB-Electronic	UEK-2000, Converter	0.8 dB	20 dB	600 DM	2 m IF, LO Output
SSB-Electronic	SLN 2300A, Preamplifier	0.4 dB	27 dB	420 DM	
SSB-Electronic	SP-13, Mast Mounted Pre-amp.	1.2 dB	25 dB	600 DM	

Table 1. A Current List of Pre-amplifier and Converter Manufacturers for Phase 3D (1.90DM = \$1.00 USD)



The SETI League, Inc.
a nonprofit educational and scientific corporation
Searching for Extra-Terrestrial Intelligence

Are We Alone?

While we search for the ultimate DX, The SETI League, Inc. salutes Amsat and the Phase 3D team for bringing us one step closer to the stars.

Like Amsat, The SETI League is participatory science. We are the international grass-roots organization dedicated to privatizing the electromagnetic Search for Extra-Terrestrial Intelligence. Together, our twelve hundred members in sixty countries are keeping alive the quest for our cosmic companions.

Visit our extensive website at www.setileague.org, write to us, or email your postal address to join@setileague.org and we will send you a free membership brochure.

Together, there is no limit to what we might discover.

Offices:
433 Liberty Street
PO Box 555
Little Ferry NJ
07643 USA

Phone:
(201) 641-1770

Facsimile:
(201) 641-1771

Email:
info@setileague.org

Web:
www.setileague.org

President:
Richard Factor

Registered Agent:
Marc Arnold, Esq.

Secretary:
A. Heather Wood

Treasurer:
Martin Schreiber, CPA

Executive Director:
H. Paul Smith, Ph.D.

Trustees:
Richard Factor
Marc Arnold
Martin Schreiber

Advisory Board:
Anthony Agnello
Paul Anderson
Sir Arthur C. Clarke
Robert S. Dixon, Ph.D.
Frank D. Drake, Ph.D.
Malcolm I. Raff, Ph.D.
Clifford Stoll, Ph.D.

Phase 3D Telemetry Program Available

Stacey Mills, W4SM

A zip file (555K) containing my Phase 3D telemetry decoding program (P3T.exe), as well as some additional supporting files is now available at: www.cstone.net/~w4sm2/software2/P3t_AP.zip

The program will run on Win95/98/NT/2000 platforms. Additional programs are under development for MacIntosh and Linux platforms. A 400 bps PSK demodulator, as used with AO-13, is required. Hardware and DSP demodulators are available. Additional information regarding demodulators, and the telemetry format can be found at: <http://www.amsat-dl.org/p3d/>

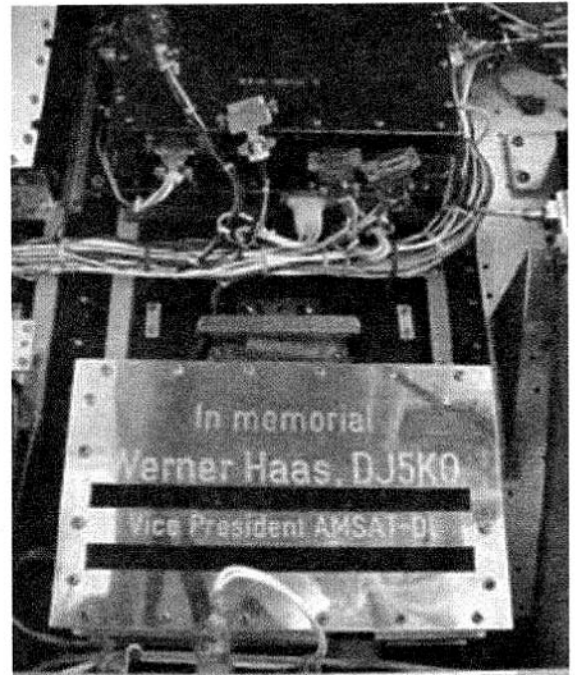
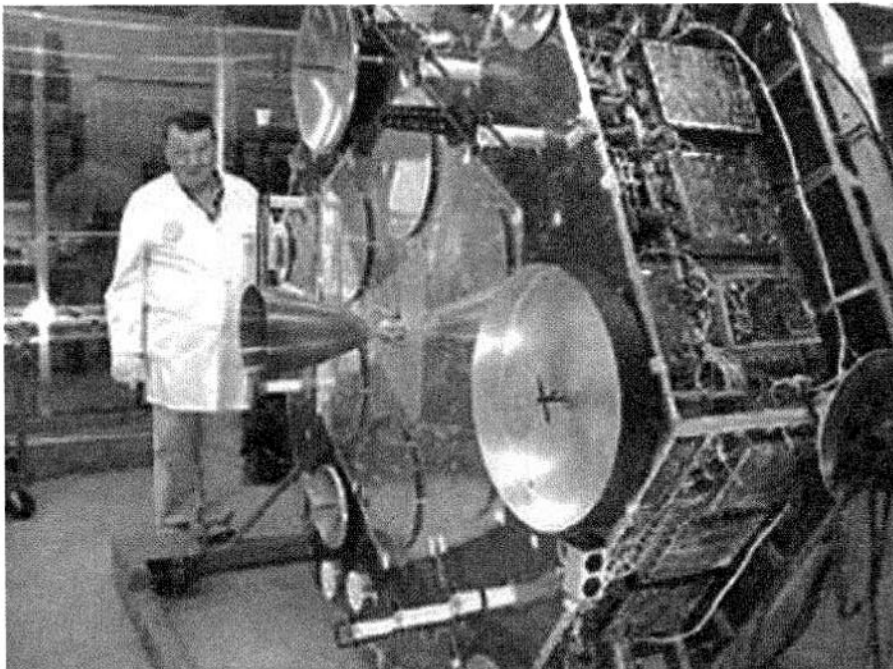
Please read the "readme.txt" file before attempting to install this software. A help file is also provided. My ability to answer specific questions regarding this software is virtually zero for the foreseeable future, given the extreme efforts required for commissioning Phase 3D. However, if you post questions to the amsat-bb, other users may be able to help and if (when) true bugs are found and brought to my attention, I will make every effort to correct them ASAP. "It would be nice ifs....." will be addressed as time allows, but probably not for a while.

NOTE that I am releasing this software as freeware, but if you like it, in the spirit of support for amateur satellite efforts, I ask that you make a minimum \$20.00 contribution to AMSAT in the name of P3T. Additional information regarding a support donation is present in the "readme.txt" file.

These promise to be exciting times!!

Enjoy,

Stacey, W4SM



Werner Haas, DJ5KQ became a Silent Key in July 2000 and did not live to see Phase 3D obtain orbit. Werner designed and constructed many of Phase 3D's components as well as components for AO-10 and AO-13. As a tribute to Werner's dedication and service to AMSAT, the laser module was mounted in a case with an engraved inscription. Long may Phase 3D fly!

Field Ops Update: Publicizing AO-40

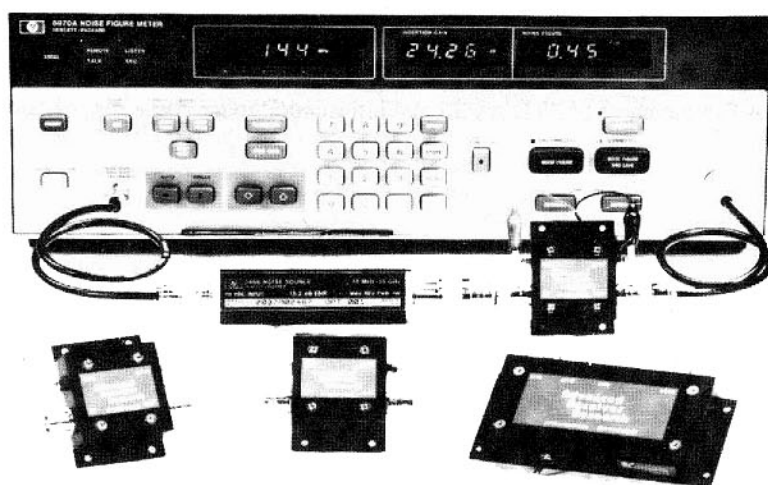
Barry A. Baines, WD4ASW

Phase 3D in orbit! What an exciting time it is for the various AMSAT organizations and the many volunteers around the world who helped create Amateur Radio's most versatile satellite.

Now that our satellite is in orbit, the Field Ops Team is gearing up to spread the word about AO-40's status and to advise potential users of Amateur Radio's newest satellite - the particulars about AO-40, ground station requirements, etc. We expect that interest will be generated in two phases: a)

immediately after launch, and b) when the satellite will be made available for general amateur use. Clearly, we are currently in the first phase. Now is a great time to educate people about what to expect during the check-out phase as the satellite transitions to general amateur service and provide information on ground station requirements. As the satellite is maneuvered into its final orbit over the next year, there will also be activity on the ground as amateurs prepare their stations to utilize the satellite when it is fully available for general amateur use.

High Performance vhf/uhf preamps



Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
P28VD	28-30	<1.1	15	0	DGFET	\$29.95
P50VD	50-54	<1.3	15	0	DGFET	\$29.95
P50VDG	50-54	<0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$69.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	<1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	<0.55	16	+12	GaAsFET	\$109.95

Every preamplifier is precision aligned on ARR's Hewlett Packard HP8970A/HP346A state-of-the-art noise figure meter. RX only preamplifiers are for receive applications only. Inline preamplifiers are rf switched (for use with transceivers) and handle 25 watts transmitter power. Mount inline preamplifiers between transceiver and power amplifier for high power applications. Other amateur, commercial, and special preamplifiers available in the 1-1000 MHz range. Please include \$2 shipping in U.S. and Canada. Connecticut residents add 6% sales tax. C.O.D. orders add \$2. Air mail to foreign countries add 10%. Order your ARR RX only or inline preamplifier today and start hearing like never before!

**Advanced
Receiver
Research**

Box 1242 • Burlington, CT 06013 • 860 485-0310



Resources

Keep in mind that there are a multitude of resources that are available that can help provide information to those interested in AO-40:

- **AMSAT Web Site:** We can't over emphasize the value of our AMSAT web site (www.amsat.org) as a resource for obtaining information on AO-40. Technical specs, photos, Keplerian elements, satellite status reports, etc. are all available on-line. Take the time to carefully review the web site for the latest information.
- **Other Web Sites:** Both the TAPR and ARRL web sites provide information concerning satellite operations. As updated information concerning digital operations is available, check out what TAPR has posted. For example, as new software drivers are developed for the various DSP modems developed by TAPR/AMSAT, they will be available on the web.
- **The AMSAT Journal:** Keep this issue! Use the other articles in this issue to serve as a resource for answering questions and providing information to those who are now interested in what is happening (and why). There will be future articles in *The AMSAT Journal* that will deal specifically with various aspects of AO-40.
- **ANS:** The AMSAT News Service (ANS) will distribute the latest information about AO-40 as it becomes available. ANS is available on the AMSAT web site, various PBBS systems, and you can have the ANS sent directly to your Internet e-mail account. For subscription information,

check the instructions on the AMSAT web page (under electronic mail list services).

- **AMSAT-BB:** AMSAT Bulletin Board is a mailing list that has several thousand subscribers. AMSAT-BB is an excellent resource for posting questions and conducting discussions of satellite related topics. Be forewarned—expect a lot of e-mail in a 'free wheeling' discussion environment.
- **AMSAT Presentation Materials:** As this article is being written, PowerPoint® presentation materials are being prepared for use at hamfests, club meetings, and other public events where Area Coordinators have been asked to provide information on AO-40. The initial distribution of this material to our Area Coordinators is expected to take place during the 2000 AMSAT-NA Space Symposium. These materials will cover not only the capabilities of AO-40, but also discuss the process of placing the satellite in its final orbit. There will also be an overview of the satellite integration that took place at Kourou.
- **Back issues of The AMSAT Journal on CD-ROM:** AMSAT will shortly have available back issues of *The AMSAT Journal* for distribution. The first CD-ROM will cover the years 1994-1999 and include all of the Journal articles pertaining to AO-40 that were published during this period.
- **AMSAT Nets:** The Sunday International AMSAT Information Net on 14.282 MHz starts with a pre-net warm-up Q&A session, an-

SSB ELECTRONIC USA

PHASE 3D Equipment Headquarters

SSB Electronic USA features world class VHF - UHF - SHF equipment. The latest gear from: SSB Electronic, Kuhne Electronic - DB6NT, M2 Antennas, Beko Electronic, EME, Procomm, AIRCOM PLUS, AIRLINK, ECOFLEX and WINRADIO is available.

- Mast Mounted Preamplifiers 144 - 2400 MHz.
- Ultra Low Noise LNA's 50.0 MHz. 24.0 GHz.
- Transverters 50 MHz. - 24.0 GHz.
- Antennas - Rotors
- Downconverters and TX Upconverters for all P3D frequencies
- Mode "S" Downconverters
- Mode "L" TX Upconverters
- Linear Amplifiers 50 MHz. - 24.0 GHz.
- Ultra Low Loss Coaxial Cable
- Transverter Kits 1.2, 2.4, 5.7 & 10 GHz.
- Parabolic Dishes

So What's New?

BEKO Electronic: 144 MHz. - 1296 MHz. Linear Amplifiers 100 Watts - 1200 Watts

DB6NT Electronic: MKU 24 OSCAR Mode "S" Downconverter IF 144 or 432 MHz.
MKU 10 OSCAR 10.451 GHz. Down Converter
MKU 24 G2 OSCAR 2.4 GHz. Transverter 1 Watt
MKU 57 OTX 5.6 GHz. OSCAR TX Upconverter *plus more.....*

ECOFLEX - LLC Super Flexible Low Loss Coaxial Cable

SSB Electronic: UEK-3000SAT Mode "S" Downconverter IF 144 or 432 MHz.
UTM-1200 DLX Mast mounted 1269 MHz. 15 Watt TX Upconverter
UTM-1200-1 1269 MHz. 1 Watt TX Upconverter
SP-2000 & SP-7000 Heli-Filtered Mast-Mounted Preamps *plus more.....*



SSB
Electronic USA

For complete specifications and prices, please visit our WEB SITE: www.ssbusa.com

Phone 570-868-5643

New Hours: MTWTFSS
9:00 AM - 11:00 PM

124 Cherrywood Dr.
Mountaintop, PA 18707

nouncements, etc. at 1800 UTC followed by the Formal net at 1900 UTC, which includes reading the ANS Bulletins. Net control stations are Keith Pugh, W5IU and Larry Brown, W7LB. If you don't have e-mail nor Internet capability, here is a way to receive the ANS bulletins. There are also several 80-meter AMSAT-NA nets on Tuesday on 3.840 MHz. The East Coast AMSAT Net is at 2100 Eastern Time followed by the Mid-America AMSAT Net at 2100 Central Time and the West Coast AMSAT Net at 2000 Pacific Time. In the UK, the AMSAT-UK net is Sunday at 1015 local on 3.780 MHz with Richard Limebear, G3RWL as net control.

- **Houston AMSAT Net:** For those with TVRO capability or Real Audio® capability, the Houston AMSAT Net is at 2000 Central Time on Tuesday evenings (0200 UTC Wednesdays) on 145.450 MHz (-) with the net broadcast simultaneously on the TVRO satellite and Real Audio®, which is available at <http://www.amsatnet.com>. The satellite transponder normally used is C-Band TVRONet on GE-4,

Transponder 16 upper (H), 5.8MHz wideband audio located at 101° west (4DTV satellite S4, channel 952). However, as of 08 October 2000 they were temporarily on Transponder 14. For the latest transponder information, check www.amsat-net.com.

What Do You Want To Do While A Satellite's Not In View? GET THE ATV BUG!



NEW 70cm 20W ATV Transceiver TC70-20 \$529

Use your same 70cm satellite beam with this unit to show your shack, satellite tracking, home video tapes, retrans Shuttle video, do public service, etc. Just add camera, TV set and 13.8V@5A - it's easy!

HAMS: Ask for our free 10 pg ATV Catalog!

We have it all, downconverters, transmitters, antennas, all mode linear amps, etc. for the 70cm thru 3cm ATV bands.

Check out our web site: <http://www.hamtv.com>

P. C. Electronics
2522 PAXSON Ln, ARCADIA, CA 91007
CALL (626) 447-4565 or FAX 626-447-0489
WEB: WWW.HAMTV.COM - Email: TOM@HAMTV.COM

Congratulations AMSAT On The Launch Of Phase 3D

NOW IS THE TIME TO SUBSCRIBE

OSCAR

Satellite Report

Published twice a month to keep you informed of what is happening in Space Communications, DX, Keps, What's Up, What's Not, and Who's On!

USA \$35 - Canada \$38 - DX \$46 per Year - mailed First Class!

ORDERS 1-800-557-9469 ORDERS

815-398-2683 VOICE 815-398-2688 FAX

VISA - M/C - AMEX

ATVQ@hampubs.com OSR@hampubs.com

visit our site → <http://www.hampubs.com>

Harlan Technologies - 5931 Alma Dr. - Rockford, IL 61108

Also Publishers of

Amateur Television Quarterly

Spreading the Word

During the period between launch and initial availability of AO-40 for amateur use there are a variety of activities that we can undertake to help build interest in satellite communications in general and AO-40 in particular. These opportunities include:

- **Serve as a Local Resource:** Given the wealth of materials that are available, spread your knowledge to others. Take advantage of situations which allow you to address local interest, whether it is discussing AO-40 on the local two meter net or talking it up at a club meeting.
- **Give Presentations at Clubs and Hamfests:** Starting with the Power-Point files mentioned above, tailor the materials to fit the needs of your audience and the scope of your presenta-

tion. At hamfests, set up a laptop in 'Slideshow Mode' to provide a continuous running of materials. Hamfests are great places to make available AMSAT resources. AMSAT will have extra copies of this issue of *The AMSAT Journal* printed that will be made available for a donation. As noted above, we will also have a new CD-ROM containing back issues of *The AMSAT Journal* available as well.

- **Encourage Telemetry Collection:** During the time that AO-40 is undergoing orbital maneuvers and check-out, we can expect telemetry to be sent via the various beacons that are available on the satellite. Check out the station requirements and determine whether you're in position to not only participate, but also use telemetry collection as a 'show and tell' to encourage other hams to set up similar

stations. Alternatively, once the telemetry program for AO-40 is released, obtain a copy to be able to let others know what the potential opportunities are for learning about the status of the satellite.

- **Telemetry Collection:** Collecting telemetry provides several benefits. First, it is an excellent way to check out your station's receiving system and provide an opportunity to peak your system for maximum efficiency. You can verify operation of your various receivers, converters, transverters, rotor system, antennas, etc. Second, telemetry collection will provide a means to verify the operation of your digital equipment. In addition, collecting information is an excellent way to gain familiarity with AO-40. Finally, data collection can potentially be useful to the ground control stations in the event they need additional data to analyze satellite performance.
- **Know Where to Obtain Assistance:** If you're asked questions about AO-40 and don't know the answers, be in a position to seek the requested information. This means being able to use the resources noted above as well as working with your local AMSAT Area Coordinator. Remember, the important thing is to get back to the person asking the question in a reasonable period of time with either a proper answer or else let them know that you are still seeking an answer to their query. Don't make promises that you will get an answer and then fail to follow up.

Keep in Mind...

With the launch of Phase 3D, AMSAT still has significant outstanding bills to pay. AMSAT has spent more money on construction and launch than has been collected to date. Your financial support is still needed to cover our expenses and ensure AMSAT's financial future.

The launch of Phase 3D opens a new chapter in the history of Amateur Radio in space. We look forward to some exciting times as well as 'rising expectations' which will develop in anticipation of Amateur Radio's newest satellite becoming available for general amateur use. In the meantime, there are plenty of activities for AMSAT members to do in preparation for the day when AO-40 is available for communications.

See ya on AO-40! ■

AMSAT-France congratulates Phase 3D team

And presents WPSKDEC a computer based demodulator software for Windows 95/98/NT

Phase-3D 400 bauds PSK telemetry real time decoding

You only need a computer with a sound card.

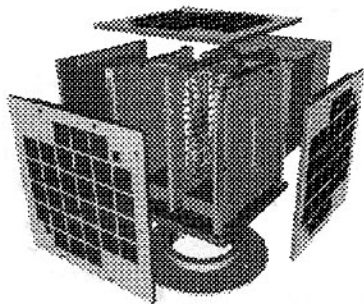
Easy Tuning with real time frequency analysis display.

Download the free Beta version **NOW!**

<http://www.amsat-france.org>

Secrétariat AMSAT-France

16, rue de la Vallée, 91360 EPINAY sur ORGE - France



AMSAT-F microsats project SATEDU

Viktor Kudielka, OE1VKW Answers *The AMSAT Journal's* Questions About AO-40 Propulsion

Kudielka: I will try to answer your questions, but you have figured out already all the important things.

The AMSAT Journal: *We are wondering how much orbital change will be accomplished with a single one hour arcjet firing. Will we be able to know right away whether the goal was accomplished, or will it have to be fired each orbit for say 10 or 100 orbits before the change is measurable?*

Kudielka: With the initial 632 kg total mass and around 0.09 kg/hour NH_3 at 4750 m/S, you get a delta-V of about 0.676 m/S ($4750 * 0.09/632$) for a one hour burn.

The velocity at perigee will be nearly 10,000 m/S; the increase is therefore not very dramatic, BUT height of apogee will increase by about 47 km! And, of course, this delta in height of apogee will also increase with the absolute height of apogee - so when, for example, Phase 3D is already at 16 hours orbital period and an apogee height of 50,000 km, a one hour burn will yield an increase of 71 km.

The accuracy of ranging is a few km, so the command stations will be able to check each single one hour burn of the arcjet.

The AMSAT Journal: *Which Keplerian parameters are most sensitive?*

Kudielka: The primary goal in the initial phase is to increase height of apogee. With constant height of perigee this means an increase of mean motion. Due primarily to the oblateness of the Earth, but also due to gravitational influences of the Moon and the Sun, the argument of perigee and RAAN (longitude of the ascending node) are changing. Therefore the command stations will have to adjust the attitude of the spacecraft, either at every perigee pass by a few tenths of a degree or at some greater intervals correspondingly.

The AMSAT Journal: *The firings are at perigee but that mainly changes the apogee, is that correct?*

Kudielka: Yes, correct.

The AMSAT Journal: *We understand that the 400N motor produces a high thrust, but only for a short time. With the fuel capacity of Phase 3D how many seconds would the 400N motor operate if it was fired only once to fuel depletion?*

Kudielka: 200 kg of $\text{MMH}/\text{N}_2\text{O}_4$ will be consumed in 1500 seconds, 25 minutes.

The AMSAT Journal: *We know that the arcjet consumes 24mg/S of ammonia. So with 52kg, it can run for 600 hours.*

Kudielka: Correct. That means also about 600 ignitions - to be controlled and checked by our command stations!

The AMSAT Journal: *We have studied various published information comparing the 400N and arcjet motors, but don't understand the numbers. For example the 400N motor has a delta-V 1150m/S and the arcjet delta-V is 450m/S. Does this mean that if the arcjet ran for all 600 hours it would accomplish 40% as much ($450/1150$) as the 400N could if it ran until all the fuel was used up?*

Kudielka: Roughly your figures are OK. The delta-V depends on the ratio of the propellant used and the current total mass - which changes with the use of propellant. So if you use the arcjet propellant first, the delta-V of the arcjet will be smaller than if you used it after the burns of the 400 N motor, when the total mass is 200 kg less. But there are also other considerations. The major inclination change has to be done with the 400 N motor; it wouldn't be feasible to do it with the arcjet. Secondly, although the very same 400 N motor has worked perfectly at a recent Jupiter mission, you want to pressurize the propellant tanks only shortly before usage, in case there are any leakages. Just to be safe.

I hope, I have answered all you asked - let's hope that everything goes as planned, our command stations have a tremendous task ahead!

Vy 73, Viktor W. Kudielka, OE1VKW

Perspectives on AMSAT OSCAR 40's (AO-40's) Orbital Evolution:

A 2001 Space Odyssey

Ken Ernandes, N2WWD

AMSAT OSCAR 40 (AO-40 – formerly known as Phase 3D) was launched to orbit on board an Ariane 5 booster, Arianespace flight 135 on 16 November 2000 at 0107 UTC. The spacecraft was released from the launch vehicle's upper stage 42 minutes 58 seconds after liftoff, placing the spacecraft into its planned *Geostationary Transfer Orbit* (GTO).

The GTO is the initial orbit established to accommodate the launch's primary payload: PanAmSat PAS-1R. However, AO-40 carries a significant amount of propellant for both its 400N bi-propellant thruster and its 0.1N arcjet thruster. These two thrusters provide the capability to maneuver the spacecraft from the GTO to the orbit that best accommodates AO-40's Amateur Radio communications mission. The maneuver sequence to establish the final orbit will be accomplished over the next 300 days or so, resulting in large changes to the orbit over the coming year. AO-40's orbital evolution during the year 2001 and beyond should prove to be an interesting odyssey.

[Note that I included a glossary of key terms at the end of this article to define terms that may be unfamiliar to the reader. These terms are presented in *Italics* the first time they appear.]

Initial Orbit

AO-40's GTO has a 595-km *perigee* altitude, a 39413-km *apogee* altitude, and a 6.5° *inclination*. Apogee and perigee occur nearly on the equator (i.e., within one degree of latitude). This initial orbit has an approximately 711 minute (11.9 hour) *period*, which is the time needed to complete one orbit of the Earth. Figure 1 illustrates AO-40's first orbit of the Earth.

Orbital Characteristics

Due to the differences between AO-40's orbital apogee and perigee heights, the ground coverage *footprint* varies. At perigee, the satellite's

footprint covers only 4% of the Earth's surface, but coverage increases to 43% at apogee. Figures 2 and 3 show the approximate footprint for apogee and perigee respectively, centered on the satellite's longitude.

At apogee, the satellite has coverage to latitudes more than 80° North and South of the equator. At apogee, it's possible for communications by ground stations separated by more than 18000 kilometers (more than 11000 miles).

The GTO is highly elliptical as dictated by the large difference between the apogee and perigee altitudes. Satellites in highly elliptical orbits spend the majority of their time near apogee where they move relatively slowly, due to *Kepler's Second Law* of orbital motion. Since AO-40 spends most of its time near apogee, the typical footprint covers more than 40% of the Earth's surface. The 40% coverage rule of thumb is valid for approximately two-thirds of the time it takes to complete each orbit.

The initial Keplerian elements are listed below:

AO-40
1 93400U 00072B 00321.07636550 .00000001 00000-0 12567-4 0 13
2 93400 6.5034 247.6325 7357988 175.9296 13.3886 2.02435417 19

Satellite: AO-40

Catalog number: 93400

Epoch time: 00321.07636550

Element set: 1

Inclination: 6.5034 deg

RA of node: 247.6325 deg

Eccentricity: 0.7357988

Arg of perigee: 175.9296 deg

Mean anomaly: 13.3886 deg

Mean motion: 2.02435417 rev/day

Decay rate: 7.71000e-09 rev/day²

Epoch rev: 1

Checksum: 278

Desired Orbit

The desired orbit will provide the overall best coverage to the majority of the worldwide AMSAT membership. This is the orbit that results after completion of the thruster firing sequence. The desired orbit has a 4000-km perigee, a 47000-km apogee, and a 63° (±2°) inclination. Perigee will be in the Southern Hemisphere

with its location 45° along the orbital track prior to the *ascending node*; apogee will be in the Northern Hemisphere, 45° prior to the *descending node*.

This desired orbit will provide coverage of 19% of the Earth's surface at perigee and 44% coverage of the Earth's surface at apogee. Typical coverage will be more than 42% of the Earth's surface.

An interesting property of AO-40's desired orbit is its ability to provide nearly *antipodal* coverage (i.e., point-to-point coverage at opposite sides of the Earth). This will allow stations in North America to communicate with stations in Australia, in some cases by over-the-North-Pole tracking. Such nearly antipodal coverage will not be available for higher latitude stations while AO-40 remains in its nearly equatorial GTO, but will be available once AO-40 accomplishes its inclination change. The transition from the GTO to the desired final orbit is difficult for several reasons that will be discussed in the next section.

Issues to Consider

Two key issues to consider are first, the magnitude of orbital changes that can be achieved by AO-40's propulsion system and second, the perils that can cause a catastrophic decay of a highly elliptical orbit. Let's consider each of these.

Propulsion System Maneuver Capability

AO-40's maneuver capability is limited by the spacecraft's propellant capacity. This is governed by the ratio of propellant mass to spacecraft mass and the *specific impulse* (I_{sp}) of the propellants used. (I_{sp} is the ratio of the achievable force of thrust per unit weight of propellant.) Since spacecraft mass decreases as propellant is consumed, the propulsion system becomes more effective with each successive thruster firing. In other words, the thrusters provide more kick as propellant is consumed and the spacecraft mass decreases. This property is a significant factor in maneuver planning.

The maneuver planning sequence is designed to safely achieve the desired orbit as quickly as possible. While the details are well beyond the scope of this article, the technical-minded reader is referred to *Alternative Start Sequences and Orbital Evolution of AO-40*, Viktor Kudielka perigee, a (see reference section for further information).

Threat of Catastrophic Orbital Decay

The catastrophic orbital decay of AMSAT OSCAR 13 (AO-13) was a painful lesson in the physics of highly elliptical orbits. Specifically, the combined lunar and solar gravity imparts *perturbative forces* that have significant effects

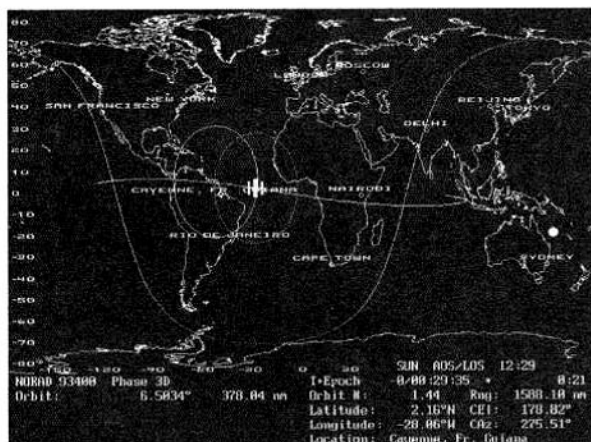


Figure 1. AO-40's First Orbit, 16NOV00.

on highly elliptical orbits. These forces are stronger in orbits with higher inclinations and higher eccentricities. One of the more noticeable effects is the direct exchange of apogee and perigee altitudes. With these perturbations, apogee altitude can increase with corresponding perigee decreases or the opposite effect of apogee decreasing with corresponding perigee increases can occur. The former case led to the demise of AO-13's orbit. The AO-40 maneuver plan was made with high regard to this phenomenon, ensuring the latter case of apogee decreases and perigee increases, thus avoiding catastrophic decay.

Maneuvers and Orbital Evolution

The arcjet thruster will provide periodic firings over the first nine months to raise apogee to an altitude between 60000 and 70000-km. Apogee is raised much higher than the final desired orbit to accommodate the inclination increase (as will be explained shortly). During this period, *argument of perigee* will drift due to perturbative forces from its initial value (near 180°) to a value around 270° , placing apogee at the orbit's northernmost latitude. The perturbative forces will also cause apogee to decrease while perigee increases at the same rate.

The arcjet thruster achieves a very high I_{sp} . The high I_{sp} is achieved through the use of large amounts of electrical power consumed by the thruster. When active, this thruster will consume the bulk of available spacecraft electrical power. Thus the spacecraft will not be available for general amateur radio communications until the arcjet maneuvers are complete.

The bi-propellant thruster will then be used to begin increasing the inclination over a period of 5 to 6 weeks. The high apogee altitude is now used as part of the maneuver strategy. Once again Kepler's second law comes into play in that the satellite has a much slower orbital speed at a higher apogee. The slower speed makes it much easier to re-direct the orbital velocity and thus cause the desired inclination increase. The inclination will ultimately be changed to $63^\circ \pm 2^\circ$, depending on the *right ascension of the ascending node (RAAN)*. At this point, the perturbative forces will cause argument of perigee to drift from 315° to 225° while apogee continues to decrease at the same rate as apogee increases. A more stable orbit cannot be achieved because of the limitations of AO-40's propellant mass to dry spacecraft mass ratio.

Summary

AO-40's long and exciting orbital journey has just begun. The spacecraft is presently maneuvering out of its GTO and increasing its apogee altitude, using the arcjet thruster. These maneuvers will continue for approximately nine months and the arcjet thruster will consume most of the spacecraft's available electrical power. The spacecraft will become available for general amateur communications after completion of the arcjet maneuvers. Following the arcjet maneuvers, the bi-propellant thruster will be used

to increase the inclination above 60° . At this point, AO-40 will have reached its desired orbit, which will be the dawn of a new era in amateur satellite communications.

Glossary of Key Terms

Antipodal – geographically opposite points on the Earth.

Apogee – An orbit's highest altitude.

Argument of perigee – The Earth-central angle measured from the ascending node to perigee, in the direction of satellite motion.

Ascending Node – an orbit's South to North equatorial crossing.

Descending Node – an orbit's North to South equatorial crossing.

Footprint – a satellite's coverage of the Earth's surface.

GTO – Geostationary Transfer Orbit which is an intermediate orbit designed to insert satellites into a geostationary orbit at apogee, using a thruster firing.

Inclination – The tilt angle of an orbit's plane relative to the equator. Inclination specifies the satellite's northernmost and southernmost overflight latitudes.

Isp – see specific impulse.

Kepler's Second Law – The law of orbital motion that states an orbiting object sweeps out equal areas in equal intervals of time.

Perigee – An orbit's lowest altitude.

Period – The time required to complete one orbit.

Perturbative forces – Natural forces that cause changes to an orbit other than what would be produced by pure Keplerian motion.

Right ascension of the ascending node (RAAN) – the angle measured eastward from the Vernal Equinox to the orbit's ascending node.

Specific Impulse (I_{sp}) – The ratio of the force of thrust per unit weight of propellant.

UTC – Universal Time Coordinated.

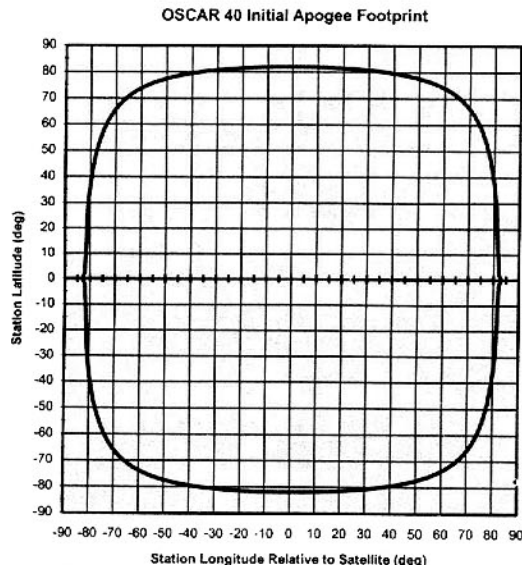


Figure 2. AO-40's Apogee Footprint

Vernal Equinox – A virtually fixed direction in space in which the Sun appears to make a South to North equatorial crossing at the beginning of spring in the Northern hemisphere.

References

Planning Meeting for the AO-40 Orbit and Orbital Maneuvers, Peter Guelzow, DB2OS, *The AMSAT Journal*, Volume 23, No. 4, July/August 2000.

Launch System / Spacecraft Interface Control File, AMSAT P3D, Section 3.4.1, Arianspace, DCI 10/480.

Alternative Start Sequences and Orbital Evolution of AO-40, Viktor Kudielka, *Proceedings of the 15th AMSAT Annual Meeting and Space Symposium*, Toronto, Canada, 1997.

AO-40 - Feasibility Study of Launch Sequences and Orbits, Viktor Kudielka, OE1VKW and Walter Drahanowsky, OE1WDC, Austrian Radio Amateur Society, Radio-Amateur-Club of the Technical University Vienna, May 1994. ■

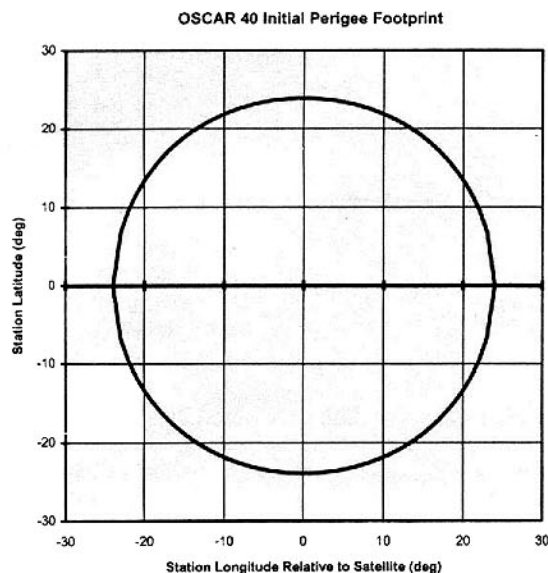


Figure 3. AO-40's Perigee Footprint.

CONGRATULATIONS

to **AMSAT** on the successful launch
of **Phase 3D**.

*To keep up with the latest news and trends in
Amateur Radio and Amateur Satellites, be sure
to subscribe to CQ Magazine*

Subscribe online at: www.cq-amateur-radio.com



CQ The Radio Amateur's Journal
25 Newbridge Road, Hicksville, New York 11801

*Please start my CQ subscription with the next available issue, for the term/rate
checked at right. I am enclosing payment or charge information with my order.*

	USA	VE/XE	Foreign
1 Year	m \$31.95	m \$44.95	m \$56.95
2 Years	m \$57.95	m \$83.95	m \$107.95
3 Years	m \$83.95	m \$122.95	m \$158.95

All prices in US dollars

Name _____

Address _____

City _____ State _____ Zip _____

☐ Check ☐ MasterCard ☐ VISA ☐ AMEX ☐ Discover

Card No. _____

Expires _____

Signature _____

First issue should arrive within 6-8 weeks to US addresses

Accept the challenge.
Join the fun.
Read CQ.

Phone 516-681-2922
FAX 516-681-2926

Phase 3D Frequencies

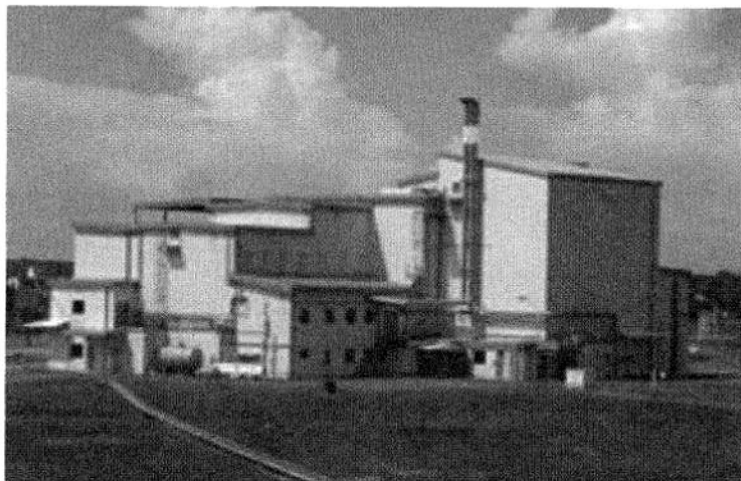
Uplink	Digital	Analog
15 m	none	21.210 - 21.250 MHz
12m	none	24.920-24.960 MHz
2m	145.800 - 145.840 MHz	145.840 - 145.990 MHz
70cm	435.300 - 435.550 MHz	435.550 - 435.800 MHz
23cm(1)	1269.000 - 1269.250 MHz	1269.250 - 1269.500 MHz
23cm(2)	1268.075 - 1268.325 MHz	1268.325 - 1268.575 MHz
13cm(1)	2400.100 - 2400.350 MHz	2400.350 - 2400.600 MHz
13cm(2)	2446.200 - 2446.450 MHz	2446.450 - 2446.700 MHz
6cm	5668.300 - 5668.550 MHz	5668.550 - 5668.800 MHz

Downlink	Digital	Analog
2m	145.955 - 145.990 MHz	145.805 - 145.955 MHz
70cm	435.900 - 436.200 MHz	435.475 - 435.725 MHz
13cm(1)	2400.650 - 2400.950 MHz	2400.225 - 2400.475 MHz
13cm(2)	2401.650 - 2401.950 MHz	2401.225 - 2401.475 MHz
3cm	10451.450 - 10451.750 MHz	10451.025 - 10451.275 MHz
1.5cm	24048.450 - 24048.750 MHz	24048.025 - 24048.275 MHz

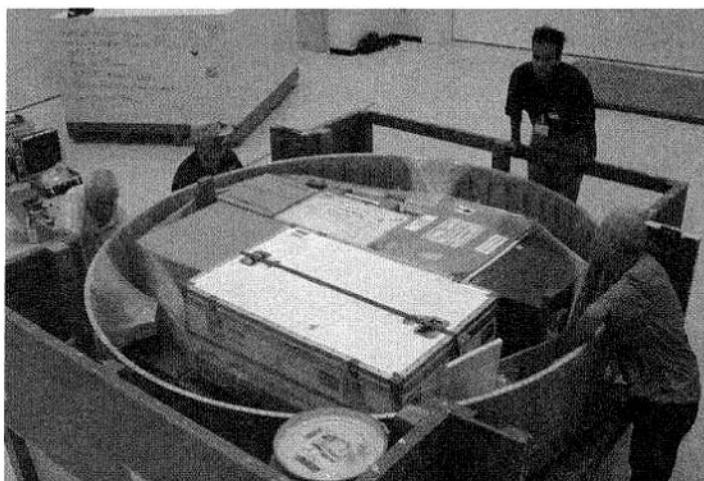
Telemetry Beacons (IHU)	General Beacon (GB)	Middle Beacon (MB)	Engineering Beacon (EB)
2 m	none	145.880 MHz	none
70cm	435.450 MHz	435.600 MHz	435.850 MHz
13cm(1)	2400.200 MHz	2400.350 MHz	2400.600 MHz
13cm(2)	2401.200 MHz	2401.350 MHz	2401.600 MHz
3cm	10451.000 MHz	10451.150 MHz	10451.400 MHz
1.5cm	24048.000 MHz	24048.150 MHz	24048.400 MHz

The Phase 3D Launch Campaign: A Photo Essay from Kourou

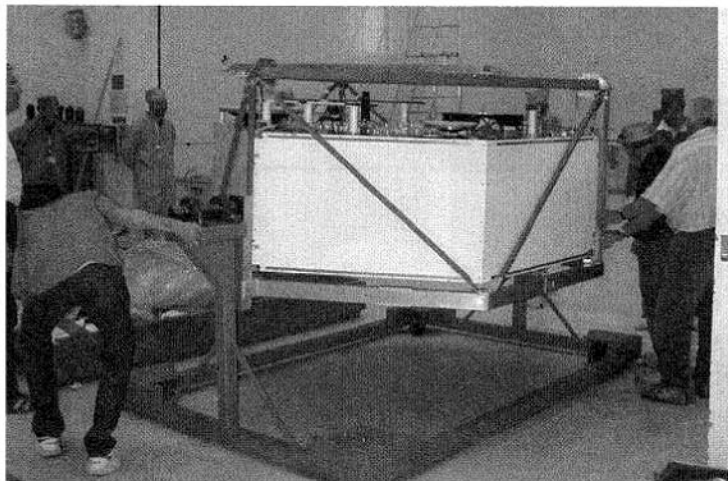
Dick Daniels, W4PUJ



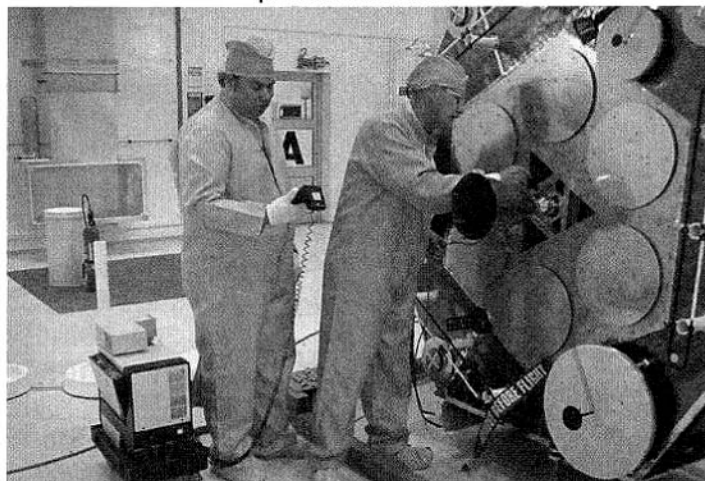
The launch team's home away from home. Building S3A where the Phase 3D final assembly, checkout and fueling took place, is one of the original structures in the launch area and the one where all of the Phase 3 satellites have been processed.



Unpacking begins in the airlock of S3A. Shown are (L-R), Konrad Mueller, Lou McFadin, Jay Ramdas, and Chuck Green. The SBS structure is at the top, the 400N motor container at lower left and the white box containing the solar arrays near the center. An unbelievable amount of stuff was packed in this box.



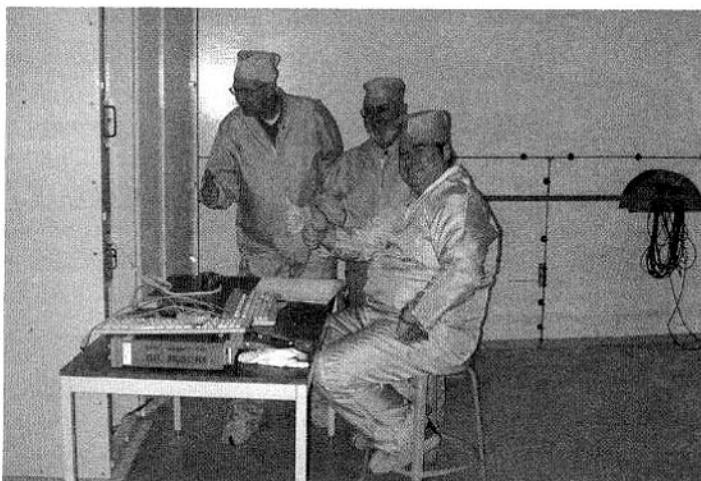
After being mounted on the Rotisserie handling fixture, the spacecraft is rolled out of the airlock into the clean room.



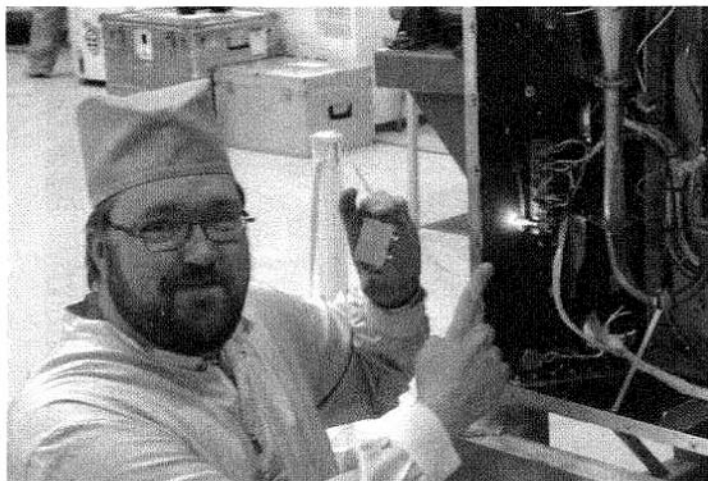
One of the first activities to conduct is a leak test of the propulsion system. After pressurization of the system, Peter Guelzow and Dick Daniels are checking for leaks using a very sensitive helium detector.



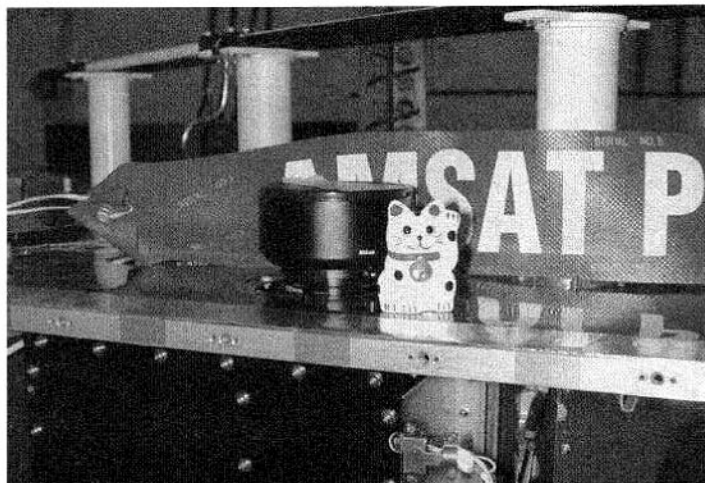
The spacecraft checkout team arrives and immediately sets up shop for an intense, one week check out session of the spacecraft's RF and digital systems.



Peter Guelzow successfully brings up the ground command and telemetry system on the first try. With him are Chuck Green and Lou McFadin.



Michael Fletcher pointing out the fix for a problem that caused the only major problem during checkout. Voltage fluctuations on a lightly loaded 28V line had caused a FET to fail in the 10 GHz exciter. The fix was to place a small light bulb on the line to load it down. Once in orbit and the spacecraft is powered up, the problem will go away and the bulb which draws a small amount of current is free to burn out.



As part of the Phase 3D reliability assurance and quality control program, Miki Nakayama of JAMSAT provided a small Japanese good luck figure which is shown near one of the SCOPE camera lens. The little guy seemed to be at work as evidenced by the relatively problem free checkout activity.

To be Continued.....

AMSAT®

Radio Amateur Satellite Corporation
850 Sligo Ave., Suite 600, Silver Spring, MD 20910 USA
Telephone 1-301-589-6062 Fax 1-301-608-3410

AMSAT® MEMBERSHIP FORM

_____ New AMSAT® Membership (includes \$15 for *The AMSAT Journal*)
 \$36 United States
 \$41 Canada
 \$45 Elsewhere (includes airmail)

_____ Clubs, societies, schools, libraries \$50

_____ Life Membership \$720

_____ AMSAT® Renewal (prices same as above)

Old Member Number _____

Name _____

Callsign _____

Street _____

Phone _____

City/State _____

Zip/Postal Code _____

Country _____

E-Mail Address _____

VISA/MC No. _____

Exp. date _____

Method of Payment _____ check _____ cash _____ charge
 Make checks (U.S. bank only) payable to AMSAT



Lift Off!



As a proud contributor to the Phase 3D fund, **ARRL**, the **national association for Amateur Radio**, congratulates **AMSAT** on the launch of Phase 3D—the largest, most sophisticated Amateur Radio satellite ever created!

The flight of Phase 3D inaugurates a new era in amateur satellites, providing enormous benefits not only for the **AMSAT** community, but all of Amateur Radio.

You can count on **ARRL** to continue to support amateur satellite operators through our national and international advocacy efforts, and by publishing, in both print and electronic media, the most up-to-date information and educational material available.

See our new Web site at **www.arrl.org**. Better yet, become a member by simply calling (toll free) **888-277-5289**.

ARRL The national association for
AMATEUR RADIO

225 Main Street • Newington, CT 06111-1494

TS-2000

Then There Was Light...



**World's
1st
HF Backlit
Front Key
Panel**

...The All New TS-2000 Multi Band/Multi Mode Transceiver

Coming Soon!

The all new Kenwood **TS-2000** series transceiver offers today's demanding Amateur operator high performance standards without the compromising limitations found in other similar multi-band, multi-mode transceivers. The **TS-2000** offers users three distinct operation platforms, the traditional transceiver with full function front panel, or the high-tech looking "silver box" version that allows mobile operation with the new RC-2000 compact control head, or the ARCP-2000 computer control program making the **TS-B2000** functional from your personal computer. The new **TS-2000** offers 100 watts on HF, 6 meters and 2 meters, 50 watts on 70cm, and when you install the optional UT-20 1.2 GHz module at 10 watts, you will have assembled the most complete dual receiver multi-mode transceiver ever produced. If you are waiting for PH3D, you will be happy to know the **TS-2000** is transverter frequency display function ready to work the latest satellite frequencies available.

IF stage DSP in the main band and AF stage DSP in the sub-band provide unparalleled noise reduction performance. Because the **TS-2000** has a built-in TNC, DX Packet cluster is available on the sub-band and can automatically shift the desired HF or 6 Meter frequencies direct to the main band for instant contacts. A weekend DXer's dream come true. You will also be sure to enjoy the built-in antenna tuner, 5+1 antenna ports, RS-232 terminal and the world's first HF fully backlit front control panel.

The **TS-2000** multi-band multi-mode transceiver, the most high performance Amateur Radio ever produced.

KENWOOD
COMMUNICATIONS CORPORATION

AMATEUR RADIO PRODUCTS GROUP
3975 Johns Creek Court, Suwanee, GA 30024
P.O. Box 22745, Long Beach, CA 90801-5745, U.S.A.
Customer Support: (310) 639-5300 Fax: (310) 537-8235
Y2ARD 2048 #110800



ISO 9001
JQA-1205
Communications Equipment Division
Kenwood Corporation
ISO9001 certification

INTERNET

Kenwood Website
<http://www.kenwood.net>
Kenwood Information
<http://ftp.kenwood.net>